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BULLETIN
OF THE
INTERNATIONAL RAILWAY CONGRESS
ASSOCIATION
(ENGLISH EDITION)

[656. 254]

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

13th SESSION (PARIS, 1937).

QUESTION IX.

Results obtained from the automatic and distant operation of signals and points, and from locomotive cab signals.

REPORT

(Italy, Switzerland, Jugoslavia, Bulgaria, Rumania, Greece, Turkey, Egypt, Spain, Portugal and Colonies),

by Carlo BELLOMI,

Inspecteur en chef supérieur au Service des Travaux et des Constructions auprès de la Direction Générale des Chemins de fer de l'État (Italy).

and Gino MINUCCIANI,

Inspecteur en chef au Service du Matériel et de la Traction des Chemins de fer de l'État (Italy).

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Preface.

Question IX of the Paris Session differs somewhat by its nature from the object of the questions on signalling discussed at former Congresses. It is for this reason that in the present Report we have omitted the descriptions of the various apparatus, in an endeavour to remain within the limits imposed by the available space, and to concentrate on the point of view of operation, i.e. on the principles and regulations.

* * *

This Report has been divided into two parts.

Part I deals with questions relating to automatic block signalling, i.e. the whole of the installations forming a system of « train spacing » in which the block signals are operated automatically by the passage of the trains themselves, usually by means of the track circuits.

Part II deals with questions relating to the remote control of points and signals. It does not include questions relating to the control of points and signals from exceptional distances, due to the fact that none of the Railways which have answered to the questionnaire possesses installations of this description.

We have, therefore, limited ourselves

to matters concerning the installation and operation of and from the power boxes, i.e. boxes from which the points and signals are operated by means other than the operator's muscular effort; in other words, they are boxes in which the energy employed for the operation of points and signals is either electric, or hydraulic, or hydro-pneumatic, or still another kind of energy.

In Part II we have ignored the mechanical plants (transmission by rods or wires).

Our Report closes by giving some information about locomotive cab signals, which, however, are still in the experimental stage on the Italian State Railways. No other railway has furnished data on this subject.

* * *

PART ONE.

Automatic block signalling.

1. Statistical data.

Among the various Railways which have replied to our questionnaire, only the three mentioned below have automatic block signalling on some of their lines :

(a) The *Rumanian State Rys.*, having 11 206 km. (6 963 miles) of lines, making 11 503 km. (7 148 miles) of single track-miles of which 10 909 km. (6 779 miles) are operated under single-track working, have :

29 km. (18 miles) of line equipped with automatic block, making 38 km. (23.6 miles) of single-track, of which 20 km. (12.4 miles) are operated under single-track working, and

15 km. (9.3 miles) of non-automatic block operated entirely under single-track working.

(b) The *Northern Rys. of Spain*, having 3 811 km. (2 368 miles) of line, representing 4 610 km. (2 865 miles) of

single track, of which 3 010 km. (1 871 miles) are operated under single-track working, have :

39.705 km. (24.67 miles) of line equipped with automatic block, giving 79.410 km. (49.34 miles) of single track, operated entirely under double-track working.

(c) The *Italian State Rys.*, having 16 297 km. (10 127 miles) of line, representing a total of 20 852 km. (12 957 miles) of track, of which 12 066 km. (7 497 miles) are operated under single-track working, have :

395.5 km. (245.7 miles) of line equipped with automatic block, representing 780.85 km. of track, of which 10.15 km. (6.3 miles) are operated under single-track working, and

2 600 km. (1 616 miles) of line equipped with non-automatic block, representing 4 920 km. (3 057 miles) of single-track, of which 280 km. (174 miles) are operated under single-track working.

Although the *Madrid-Saragossa-Alicante Rys.* have automatic block signalling since 1924, we are unable to give any data concerning their lines, as no reply has been received to our questionnaire.

In this connection, we can refer the reader to the report by Messrs. A. Gibert and J. Noguès, to the Madrid Session (1930) and published in the *Bulletin of the Railway Congress*, April 1930 number, p. 1 161.

The above data are repeated in Table 1, while Table 2 shows for each of the three Railways, the percentage equipped with automatic block signalling, non-automatic block signalling, and lines operated under single-track working, to the total length of the lines or track.

Among these three Railways, the *Italian State Rys.* have the greatest number of installations of this kind, proportionally and quantitatively.

Table 2 shows that on the *Northern*

TABLE 1.
Statistical data on automatic block signalling.

		Railways.		
		<i>Rumanian State.</i>	<i>Northern of Spain</i>	<i>Italian State.</i>
1	Length in kilometres of lines equipped with automatic block signalling	29	39.705	395.500
2	Number of track-kilometres equipped with automatic block signalling	38	79.410	780.850
3	Length in kilometres of lines equipped with automatic block signalling, operated under single-track working.	20	...	10.150
4	Length in kilometres of lines equipped with non automatic block signalling	15	...	2 600
5	Track-kilometers equipped with non automatic block signalling	15	...	4 920
6	Number of kilometres equipped with non automatic block signalling operated under single-track working.	15	...	280
7	Total number of kilometres of line owned by Railway	11 206	3 811	16 297
8	Track-kilometres owned by the Railway . .	11 503	4 510	20 582
9	Number of kilometres of line operated under single-track working	10 909	3 010	12 066

Rys. of Spain automatic block signalling is employed only on double-track lines.

Those Railways using automatic block signalling have found it more convenient to apply it to double track rather than single track. This is obvious, as automatic block signalling is used either to increase the safety of operation or the capacity of the line. The latter is obtained more easily on double track, as the direction of traffic is determined for each track, and therefore it would be possible, if needed, to have one train in each section.

This is only possible on single track when the running direction of trains between two consecutive stations is the same.

2. Automatic block signals.

(a) General.

Both mechanical and day-light signals may be used for automatic block signalling. The *Rumanian State Rys.* and the *Northern Rys. of Spain* have adopted colour light signals, while the *Italian State Rys.* are using mechanical signals on all their lines equipped with automatic block signalling.

The average length of the automatic block sections on the *Rumanian State Rys.* is 2 000 m. (6 560'), with a maximum of 2 140 m. (7 020'). On the *Northern of Spain* these lengths are 1 100 m. and 1 775 m. (3 610' and 5 820') respectively, and on the *Italian State Rys.* they are

TABLE 2.

		Railways.		
		<i>Rumanian State.</i>	<i>Northern of Spain</i>	<i>Italian State.</i>
1	Ratio of automatic block lines to total length of lines owned by railway	0.25 %	1 %	2.4 %
2	Ratio of track-kilometers equipped with automatic block signalling to the total km. of track owned by railway	0.33 %	1.8 %	3.8 %
3	Ratio of single-track lines equipped with automatic block signalling to the total km. of lines operated under single-track working	0.18 %	...	0.8 %
4	Ratio of non-automatic block lines to total length of lines owned by railway	0.135 %	...	16 %
5	Ratio of track-kilometres equipped with non-automatic block signalling to the total km. of single-track lines owned by railway	0.13 %	...	23.4 %
6	Ratio of single-track lines equipped with non-automatic block signalling to the total km. of lines operated under single-track working	0.14 %	...	2.33 %
7	Ratio of length of lines equipped with automatic or non-automatic block signalling to total length of lines owned by railway	0.43 %	1 %	18.4 %
8	Ratio of track-kilometres, comprising those equipped or not with automatic block signalling, to total km. of single-track lines owned by railway	0.465 %	1.8 %	27.2 %
9	Ratio of single-track lines equipped with automatic block signalling, to the total km. of lines operated under single-track working	0.32 %	...	3.13 %

5 000 m. and 6 700 m. (16 400' and 21 980') respectively. The two former Railways can, however, without any inconvenience, combine the block signal with the distant signal of the following section, thus obtaining a three-indication signal. These Railways actually use colour light signals displaying :

(a) a red light for *stop*;

(b) a yellow light to show *be prepared to stop at the next signal*;

(c) a green light for *line clear*.

A distance of 1 000 to 2 000 m. (3 280' to 6 560') between the stop signal and the distant signal is necessary, but for safety and other reasons it would not be advisable to increase this distance up to 5 000 or 6 000 m.

This is why the *Italian State Rys.* combine their block semaphore signal with the distant signal of the following section only where these signals are normally located at a short distance from

each other, which happens very seldom due to the exceptional length of the automatic block sections.

However, the *stop signal* used by the *Italian State Rys.* is a semaphore signal carrying a red rectangular arm with a white stripe. This arm is mounted on the left of the pole and displays a stop indication when the arm is in the horizontal position in daytime, and a red light at night.

The *line clear* indication is displayed as follows :

— by day; by means of the arm in the lower left-hand quadrant;

— at night, by means of a green light.

The *distant signal* is a semaphore signal with a rectangular arm, with a fish-tail end and a white stripe on an orange background. This arm is also mounted on the left of the pole.

This semaphore signal shows the stop position of the next block signal ahead when the arm is horizontal (by daytime) or by means of a yellow light at night.

If the next block signal ahead is in the *line clear* position, the distant signal shows this in the following manner :

— by day, with the arm in the lower left-hand quadrant;

— at night, by means of a green light.

(b) *Protection of junctions and stations on lines equipped with automatic block signalling.*

For the protection of their junctions and stations, the *Rumanian State Rys.* use a type of signal different from that

used for the spacing of trains; it consists of two horizontal red lights and a lunar white marker light on the right of the pole. The distant signal also carries a marker light for the purpose of showing an absolute stop.

For the protection of stations, the *Italian State Rys.* use the same signal as for the block, but for junctions they have adopted semaphore signals or two double bracket colour ligths. Furthermore, as the automatic block signals are *permissive*, they have a letter « P » on the post to distinguish them from non-permissive signals.

3. Length of automatic block sections.

In the foregoing paragraph we have given the lengths of the automatic block sections on the various Railways. These lengths, which are repeated in Table 3, bring out the reasons why the *Northern of Spain* and *Rumanian State Rys.* combine the stop signal of one section with the distant signal of the next section, while the *Italian State Rys.* cannot use such an arrangement, although it is considered very interesting and is being used in the station protection signals. We shall come back to this point in Part Two of this report. The length of the automatic block sections must be determined as a rule either by the number of trains running on that line or by bearing in mind that safety lies in the perfect operation of the track relays, which in its turn depends on the length of the track circuits.

TABLE 3.

RAILWAYS.	Length of block sections	
	Average.	Maximum.
<i>Northern Rys. of Spain.</i>	1 000 m. (3 280')	1 775 m. (5 820')
<i>Rumanian State Rys.</i>	2 000 m. (6 560')	2 140 m. (7 350')
<i>Italian State Rys.</i>	5 000 m. (16 400')	6 700 m. (21 980')

It must be noted in this respect that according to the automatic block circuits employed, a section consists of one or two track circuits, and therefore, when no repeater relays are used, the length of the section will have to be subordinated to the maximum length admitted for the perfect working of the track circuits.

We think that the *Northern of Spain* and the *Madrid-Saragossa-Alicante Rys.* (the principles used by the latter Railway are known (see report by Messrs. Gibert and Noguès, to the Madrid Session, 1930), have not met with any difficulties in regulating the track circuits, seeing that the block sections have a maximum length of 1 000 m. (3 280 ft.) only — the length of 1 775 m. (5 820') being exceptional — and that this length of 1 000 m. is admissible for a single track circuit.

Neither have the *Italian State Rys.* experienced any trouble with their automatic block sections, whose length averages 5 000 m. (16 400') with a maximum of 6 700 m. (21 980'), but they have installed repeater relays where necessary, either from a safety standpoint or from the point of view of regular running of trains, in order to avoid having track circuits of more than 1 200 to 1 500 m. (3 940' to 4 920'). Strictly speaking, the length of the block sections should decrease in the running direction, so that if the line between two stations A and B must be divided say into three sections, I, II and III starting from station A, there should be the following relation between sections L_1 , L_2 and L_3 :

$$L_1 > L_2 > L_3$$

Thus, it will avoid a train running from A to B, and leaving A immediately after the preceding train has left section I, having to stop at the block signal of section II, because, assuming that the speed of the two trains is constant, the first train will have left sec-

tion II (which is shorter than section I) before the second train sights the signal of section II.

This procedure applies only to the hypothetical case where the allowed speed on the line between stations A and B is uniform.

A more general procedure for establishing the length of the sections according to the maximum speed allowed, should be represented by means of a relation, where the time taken by a train to run through consecutive sections, should be decreasing.

Therefore, if in section I the line measures l_1 , and the speed of a train running through this section is V_1 , then the time necessary for running through this whole section I will be given as:

$$\frac{l_1}{V_1}$$

Similarly, the time necessary to run through sections II and III will be:

$$\frac{l_2}{V_2} \quad \text{and} \quad \frac{l_3}{V_3}$$

respectively.

The lengths of the successive sections should therefore be such that

$$\frac{l_1}{V_1} > \frac{l_2}{V_2} > \frac{l_3}{V_3} \dots (1)$$

This being so, if there is double track between A and B, relation (1) should be applied to the track from A towards B, and to the other track, i.e. from B towards A, the following relation should be applied:

$$\frac{l_1}{V_1} < \frac{l_2}{V_2} < \frac{l_3}{V_3} \dots (2)$$

The sections on the two tracks would therefore have different limits, which would no doubt cause complications in automatic block locations (relay boxes, etc.). Formulæ (1) and (2) cannot be applied to single-track lines.

The conclusion is that it would be desirable to systematically vary the

lengths of the sections according to the maximum speeds allowed on the lines, in all those cases where such variations are possible and convenient.

4. Overlap and approach lighting.

The *Rumanian State* and *Northern of Spain Rys.* do not have an overlap in their automatic block, i.e. an insulated track section ahead of the block signal between the joint which causes the signal to give the stop indication when a train is passing it, and the joint which, on being passed by a train, allows the preceding signal to be set at *line clear*.

The *Italian State Rys.* have an overlap on their automatic block installations. Moreover, the two former Railways have installations in which the block signals are put to danger by the first pair of wheels running over the insulated joints separating the two sections, while the latter Railway (Italy) has automatic block signalling installations in which the signals assume the stop position when the last pair of wheels run over the first insulated joint of the overlap.

The block signals on the *Rumanian State* and *Northern of Spain Rys.* are normally — i.e. in the absence of trains — in the *line clear* position. On the *Italian State Rys.* these signals will only display the clear indication when the signal ahead is *at stop and lighted*.

The *Rumanian State Rys.* have adopted *approach lighting* on 20 km. (12.4 miles) of single track. The *Northern of Spain Rys.* do not employ this system.

The *Italian State Rys.* have not adopted approach lighting, because as mentioned before, they use semaphore signals and not colour light signals. However, in order to obtain the condition by which the setting at *line clear* of a signal is determined by the position of the signal ahead and its lighting, the semaphore signals display a light by day as well as at night.

Finally, the above three Railways do not use winking lights nor signals which can be put to danger by the permanent way men.

5. Meaning of block signal indications and regulations referring thereto. — Proceeding with caution.

We shall explain in this paragraph the exact meaning given to the block signals by each Railway.

On all three Railways, viz. the *Rumanian State*, *Northern of Spain* and *Italian State Rys.*, the automatic block signals are normally at *line clear*.

When the signal is at stop, these three Railways require the engine driver to stop at the signal, *without any exception whatsoever*, and in no way is he allowed to pass these signals without having first stopped the train.

Their regulations prescribe that after a certain waiting time has elapsed (4 minutes on the *Northern of Spain*, 5 minutes on the *Rumanian State*, and 10 minutes on the *Italian State Rys.*), if the permissive automatic block signal remains at stop, the train must *proceed with caution*. The *Italian State Rys.* lines equipped with automatic block signalling are operated under the « Central Controller » system, and each semaphore carries a telephone for communication with the Central Controller (C. C.). The engine driver must follow the C. C.'s orders.

The C. C. may order the train to proceed immediately, with caution or even at normal speed if he knows the causes which have put the signal to stop, providing the causes are of such a nature as to allow the passing of the train at that speed.

On the other hand, the C. C. may prolong the waiting time of the train and then order to proceed at normal speed.

The *Northern Rys. of Spain* and the *Rumanian State Rys.* do not have tele-

phones of this kind, although they are now considering their installation.

In Italy, in case of failure of the telephone lines or in case of absence of the C. C., the driver will proceed with caution after waiting ten minutes at the block signal at stop.

When *proceeding with caution*, a train must be able to stop immediately in order to avoid accidents due to obstructions of the line or collisions with trains which might be stopped on the line.

On the *Rumanian State Rys.* when proceeding with extreme caution the speed must not exceed 15 km. (9.3 miles) per hour; on the *Italian State Rys.* the maximum speed in such case is 25 km. per hour. The *Northern Rys. of Spain* do not prescribe any maximum speed when proceeding with caution, but they require the driver to proceed *slowly* so that the train may stop at the first stop signal of whatever kind.

These regulations are imposed by the three Railways in all cases, and they must be obeyed during the day and at night, and in all sections which do not include junctions or stations.

6. Protection of junctions and stations on lines equipped with automatic block.

The *Rumanian State Rys.* and the *Italian State Rys.* do not have automatic block sections including a junction and the latter System does not have sections including a station.

The question regarding the installation of signals for the protection of a junction or a station on a line equipped with automatic block signalling will be dealt with separately for the three Railways :

(a) *Rumanian State Rys.*

This System, which has stations in automatic block sections, places a non-automatic signal at the entrance to the station, which can be put to *stop* by the station staff. This signal differs

from automatic block signals installed on open track by the absence of the special marker light installed on all automatic block signals.

(b) *Northern Rys. of Spain.*

This System also has automatic block sections including stations. An absolute stop signal is placed at the entrance to the station. This signal differs from the automatic block signals in that it carries two horizontal red lights and a marker light mounted on the right-hand side of the pole. It is controlled from the station and the signal box, if such exists.

(c) *Italian State Railways.*

This Administration has no block sections including stations and junctions, and protects stations on automatic block lines with an absolute *stop* signal which is put *off* by the station signalman; it is a semaphore signal normally *at danger* and which does not carry the « P » sign.

In case of failure, the three Railways prescribe that the stop signal be passed only on receipt of written and signed authority from the station-master.

(d) *Conclusions.*

The three Railways mentioned above agree on these fundamental points :

the stations and junctions on lines equipped with automatic block signalling must have their own absolute *stop* signal to protect them, whether they are in a block section or not;

this signal must in all cases differ from the permissive block signals and must be controlled by the station staff.

7. Lines with long tunnels, equipped with automatic block signalling.

Of these three Railways, the *Italian State* alone has long tunnels on such lines. These are the « Grande Galleria

dell'Appennino » on the Bologna-Florence « Direttissima » and the Vivola, Montorso and Massico tunnels of the Rome-Naples « Direttissima ». The two lines are electrified and offer perfect visibility conditions, and therefore the signals are not duplicated with audible signals.

In these tunnels, the length of which considerably exceeds that of the block sections, colour-light signals have been adopted, which are operated and passed under the same conditions as the open-track mechanical signals.

8. Lines equipped with automatic block, which can be used for traffic in either direction.

Of the three Railways mentioned, only the *Italian State Rys.* and the *Rumanian State Rys.* have lines equipped with automatic block, which can be used for traffic in either direction. On both Railways, the direction of the traffic is determined by an official who, in the case of the *Italian State*, is the Central Controller.

The signals used are special signals on the *Rumanian State*, while on the *Italian State Rys.* they are ordinary block signals. These signals are operated manually on both Railways, but are track-circuit controlled.

The regulations in case of failure are the same as on lines used for traffic in a single direction. The same applies to the regulations to be observed when proceeding with caution.

9. Protection of a train normally or accidentally stopped at any point of an automatic block section.

An interesting question arises in this connection, namely, whether the Railways consider the permissive automatic block signals sufficient for the protection of a train which is normally or accidentally stopped on open track within a block section.

Our enquiries on this question have provided the following answers :

(a) *Rumanian State.* — Protection afforded by the automatic block is considered sufficient. Supplementary regulations are given only for those cases where derailed trains have all their wheels off the rails.

(b) *Northern of Spain and Italian State.* — On double-track, trains which have stopped on open track are normally considered as sufficiently protected by the automatic block signals, during the regulation waiting time at a permissive block signal at *stop*, namely, four minutes on the *Northern of Spain* and ten minutes on the *Italian State*, but if the waiting time is prolonged, the train must be protected in the rear as usual on lines not equipped with automatic block.

The regulations relating to traffic on lines equipped with automatic block signalling and used for traffic in both directions are the same as those for traffic on double track.

The enquiries made in an endeavour to find out whether modifications had been made to the regulations concerning traffic under normal conditions or in case of failure on the lines equipped with automatic block signalling show that no modification has been introduced in the above regulations by the *Rumanian State* and *Northern of Spain Rys.*

The *Italian State Rys.* have introduced certain modifications in that part of the regulations affecting the operation in case of a halt at the automatic semaphore signals. According to past regulations, the guard had to wait three minutes before communicating with the C. C. and, while proceeding slowly, had to be in the engine cab. These regulations caused considerable delays and were therefore abolished and replaced by the measures stated above.

10. Technical data on automatic block signalling installations.

A. Track circuits.

It need not be said that track circuits play a very important part, if not a capital part, in central signalling plants as well as in automatic block installations. We give hereafter the information supplied by the various Railways about these installations.

Feeding track circuits. — The *Rumanian State Rys.* have 9 km. (5.6 miles) of line equipped with automatic block with A. C. track circuits and 20 km. (12.4 miles) of line with D. C. track circuits.

Batteries charged by rectifiers are used for feeding the latter; in other words, this Railway uses the floating battery system for feeding its D. C. track circuits.

The *Northern Rys. of Spain* feed the automatic block track circuits with alternating current.

Finally, the *Italian State Rys.* — which have adopted automatic block both on steam traction lines and electrified lines using three-phase and direct current — feed the track circuits with alternating current on their D. C. and A. C. electrified lines, and with D. C. or A. C. indiscriminately on their steam-worked lines.

The necessity for using A. C. for feeding the track circuits on electrified lines is obvious. This requires relays, the operation of which is not affected by the ill effects of the traction current on D. C. relays.

In the case of lines electrified with three-phase current, alternating current is used for feeding the track circuits, of a frequency differing either from the fundamental frequency of the traction current or from its third harmonic, and as the frequency of the traction current is $16 \frac{2}{3}$ cycles, the 75-cycle frequency

has been chosen for feeding the track circuits.

On steam-worked lines where track circuits are fed with direct current, the floating battery system with nickel-iron cells and copper-oxide rectifiers is used.

B. Block signal lighting.

The *Rumanian State Rys.* use A. C. for the lighting of their block signals on the 9 km. of automatic block equipped with A. C. track circuits; they use D. C. for the lighting of the signals of the remaining 20 km. of line equipped with D. C. track circuits.

In the latter case, rectifier-charged batteries are employed for signal lighting, and approach lighting is used.

The *Northern Rys. of Spain* light their block signals with alternating current, approach lighting not being used.

The *Italian State Rys.* light the automatic semaphore block signals with D. C. at all times and use floating batteries or high capacity primary batteries. These signals, as stated above, are alight day and night.

The *Italian State Rys.* have adopted approach lighting on 32 km. (20 miles) only of automatic block signalling.

In order to meet the possibility of a signal lamp burning out, the *Rumanian State Rys.* employ on their 9 km. of automatic block lighted with A. C., double-filament lamps, and they provide an independent source of energy (accumulators) for the standby filament.

Instead of double-filament lamps, the *Northern Rys. of Spain* use two lamps, both alight, one at normal voltage, the other underrun.

The *Italian State Rys.* have not considered sufficient to have standby lamps or double-filament lamps to protect themselves against the dangers which may be caused by the extinguishing of a lamp in an automatic semaphore signal at night. They are of the opinion

that when one of the two filaments burns out, the other filament will burn out too after a short time, due to the increased voltage through the remaining filament. This Railway prefers to assure the lighting in such a manner that the extinction of an automatic block signal doubles the block section.

The three Railways advise that they have never had any accidents with the automatic block, which could be traced to the extinction of a block signal light.

11. Precautions taken against dangerous failures of apparatus and devices forming part of an installation of automatic block signalling.

The following are the usual dangerous failures on lines equipped with automatic block signalling :

(a) block relays unduly remaining energized;

(b) stop signal unduly remaining in the *line clear* position.

(a) *Block relay failures.*

The causes which may prevent a block relay, i.e. a track-circuit relay, from being de-energized, may be of two kinds : they may be of an electrical or of a mechanical nature.

The former appear on electrified lines. In these cases, which occur in practically all automatic block installations on the *Italian State Rys.*, the above stated dangers (relay remaining energized) have been avoided by means of A. C. track circuits using both rails on direct current lines, and using impedance bonds for the return of the traction current; or on three-phase current lines, by the use of track circuits fed with 75-cycle A. C.

Another cause of an electrical nature may be the over-voltage on the relay feeder line, causing the armatures to stick. To avoid this, it would be necessary either to use sources which can-

not cause over-voltage (batteries) or to use relays with metal-carbon or « bi-metal » contacts.

But the causes of a mechanical nature still remain, and these are due exclusively to failures in the mechanical parts of the relays themselves. There can only be a relative protection against these failures, by using high-grade relays with the smallest possible number of mechanical parts.

To further reduce the possible and probable causes of failure of a mechanical nature, the *Italian State Rys.* have adopted on their first installation of 215 km. of double track equipped with automatic block signalling, a control system over the de-energization of the block relays, in such a manner that this de-energization of the relays becomes necessary in order to get the block signal protecting the preceding block section to give the *line clear* indication.

(b) *Block signal failures.*

All the reasons which may prevent a block signal from assuming the danger indication are of a mechanical nature. They are completely absent in light signals having a different light for each colour, and exist either in semaphore signals (or mechanical signals in general) or in light signals operated by relays.

The *Rumanian State* and the *Northern of Spain Rys.* do not take any precautions against relays unduly remaining energized; neither do they take any measures against the possibility of the stop signal itself not giving the danger indication, as these two Administrations use day-light block signals with as many lights as colours.

The *Italian State Rys.* using, as stated before, semaphore signals, protect themselves against those such signal failures by arranging for it being possible to show the *line clear* indication on a block signal only when the *stop* as-

pect is actually shown by the block signal of the following section. Naturally, this is reflected in a regulation ordering the engine driver, who passes an automatic block at danger, in the absence of the C. C. only, to proceed with caution over two block sections.

12. Light rolling stock (inspection trolleys, etc.).

The track circuits in automatic block installations do not operate properly with light rolling stock. The *Italian*, *Rumanian* and *Northern of Spain Rys.* run their inspection cars without heeding the automatic block. The running of such vehicles is regulated by the station staff, and it is not based on block intervals, but on station intervals.

13. Statistical data with reference to failures in automatic block signalling installations.

Failures in automatic block installations can be divided into two large groups :

(a) Failures against safety, by which a block signal may give a clear indication while the section itself is occupied;

(b) Failures in favour of safety, but of course detrimental to the regularity of the working, causing undue train stops.

The three Railways mentioned in this report as owning automatic block installations have never experienced any failures as those shown under (a), i.e. against safety. They have, however, experienced failures of the other kind, and both the *Northern of Spain* and *Italian State* have furnished statistical data in connection with these failures.

The *Rumanian State Rys.* are not in a position to give any information of this nature, as their automatic block installations are only in the experimental stage.

It should first be pointed out that on none of the three Railways have there

been any mishaps due to the engine driver entering an occupied section without having proceeded cautiously at sight, as prescribed in this case.

The *Northern Rys. of Spain* have furnished statistical data referring to failures in the automatic block installation between Madrid and Villalba during the years 1934 and 1935. These failures are divided into four groups and apply to :

- (a) the track circuits;
- (b) the signals;
- (c) the lines;
- (d) the feeding line.

Graphs 1 and 2 show either the failures of a different nature or the number of failures for the years 1934 and 1935, while graphs 1-b and 2-b, respectively, show for each year the number of signal-hours of failure or the percentage of interruptions in the operation of the automatic block, expressed in signal-hours.

The *Italian State Rys.* also draw up statistics and keep a record of daily failures occurring on the various installations and of the number of undue stops caused by each failure. For example, Table 4 indicates for each day of the year 1933 the causes of the stops and the number of stops due to each fault. The failures are represented by a number comprising three figures corresponding to the nature of the failure. The number of stops caused by one and the same failure is placed as an exponent of the index number of the failure, which in this case is enclosed in a rectangle.

The numbers which are not thus enclosed refer to failures causing one stop only.

The totals given at the bottom of the table consist of fractions, the numerators of which represent the number of failures and the denominators the number of stops.

The failures are divided into six large groups, which are identified by the following figures :

0, 1, 2, 3, 4, 5.

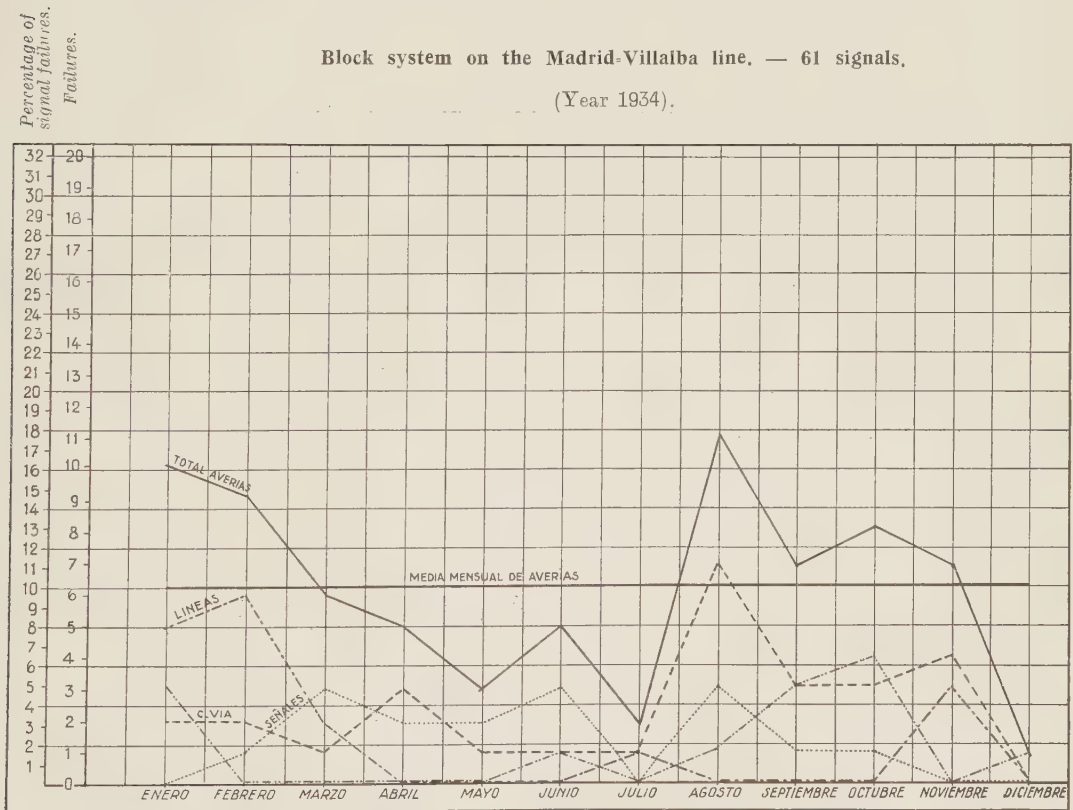
These are the first figures of the index number of the failures.

The six above mentioned groups are as follows :

- 0 — Failures in the high-tension feeding line (such failures being subdivided themselves into 15 different kinds);
- 1 — Failures in the apparatus housed in the relay cupboard (subdivided into 63 kinds);
- 2 — Failures in the track appliances (insulated joints, inductive and conductor lines cables, etc.) (subdivided into 31 kinds);
- 3 — Failures in the signals and their accessories (subdivided into 29 kinds);
- 4 — This group comprises 33 kinds of failure, which are either due to the station staff or to failures in the signal boxes in connection with the automatic block installations;
- 5 — Undefined failures or failures due to unknown persons or to negligence of permanent way men (subdivided into 12 kinds).

Block system on the Madrid-Villalba line. — 61 signals.

(Year 1934).



Graph. 1. — Northern Railways of Spain.

Explanation {
 ——— Track-circuit failures.
 Signal failures.
 - - - Failures on the line.
 - · - Failures due to faults in the apparatus.
 ——— Total number of failures.

Note: Media mensual de averias = monthly average of failures.

Italian State Railways. — Automatic block failures and corresponding train stops on Naples-Rome « Direttissima » (Year 1933).

Day	January	February	March	April	May	June	July	August	September	October	November	December
1	—	419	—	—	205	—	—	001	—	—	001 122	143
2	—	402	—	311	501	402	—	—	$\begin{bmatrix} 003 \end{bmatrix}^7 \begin{bmatrix} 121 \end{bmatrix}^2$ 405	104	505 407	$\begin{bmatrix} 220 \end{bmatrix}^2$ 001
3	—	—	121	—	—	401	114	—	$\begin{bmatrix} 001 \end{bmatrix}^4$ 128	—	—	—
4	201 506	—	—	$\begin{bmatrix} 221 \end{bmatrix}^2$	—	—	531	—	$\begin{bmatrix} 316 \end{bmatrix}^3$	—	134	—
5	—	—	—	—	411	$\begin{bmatrix} 401 \end{bmatrix}^2$ 201	$\begin{bmatrix} 005 \end{bmatrix}^3$	—	104	—	531	—
6	201	—	—	128	—	104	414 001	—	—	—	122	—
7	—	—	203	$\begin{bmatrix} 003 \end{bmatrix}^2$	—	$\begin{bmatrix} 002 \end{bmatrix}^2$ 132	—	$\begin{bmatrix} 218 \end{bmatrix}^3$ 205	$\begin{bmatrix} 001 \end{bmatrix}^2$ 531	137 137	$\begin{bmatrix} 001 \end{bmatrix}^2$ 319	—
8	—	$\begin{bmatrix} 121 \end{bmatrix}^2$ 001	$\begin{bmatrix} 201 \end{bmatrix}^3$	—	—	—	531	—	—	—	121	327
9	—	162	$\begin{bmatrix} 001 \end{bmatrix}^6$	—	327	—	210	$\begin{bmatrix} 004 \end{bmatrix}^3 \begin{bmatrix} 133 \end{bmatrix}^2$ 305	$\begin{bmatrix} 003 \end{bmatrix}^2$	—	531	405
10	—	—	205 004	—	210—125 101	—	$\begin{bmatrix} 001 \end{bmatrix}^3$ 161	—	—	—	—	319 408
11	$\begin{bmatrix} 211 \end{bmatrix}^2$	—	012	—	201	003	—	—	$\begin{bmatrix} 003 \end{bmatrix}^2$	407	$\begin{bmatrix} 003 \end{bmatrix}^3$ 012	303
12	—	—	—	—	—	108	—	307	$\begin{bmatrix} 003 \end{bmatrix}^2$ 003	004	—	—
13	—	—	—	—	$\begin{bmatrix} 011 \end{bmatrix}^2$ 502	$\begin{bmatrix} 003 \end{bmatrix}^3$	$\begin{bmatrix} 120 \end{bmatrix}^2$	—	404	$\begin{bmatrix} 001 \end{bmatrix}^2$ 140	—	311
14	—	311	—	$\begin{bmatrix} 505 \end{bmatrix}^2$ 001	—	$\begin{bmatrix} 003 \end{bmatrix}^4$	—	—	107—531 502	—	—	140

16	—	—	$\frac{2}{104}$	—	008—405 507	$\frac{2}{101}$	—	—	—	—	$\frac{2}{415}$	$\frac{2}{001}$	$\frac{2}{445}$
17	$\frac{2}{001}$	—	—	414	002 305	531	—	—	$\frac{7}{003}$	—	—	—	$\frac{5}{003}$ 319
18	427 005	—	104 125	—	001	—	—	213	—	128	319	128	319
19	005	$\frac{14}{003}$	121	—	—	307	$\frac{4}{131}$ — $\frac{128}{401}$	205 307	47	—	—	—	—
20	—	$\frac{2}{407}$	304	—	001	—	—	210	319	—	—	—	—
21	—	—	106 147	210	—	—	214	$\frac{2}{003}$	—	—	—	—	—
22	$\frac{2}{327}$ — $\frac{125}{125}$	149	302	—	—	$\frac{2}{502}$ 319	—	$\frac{13}{003}$	—	402	211 531	402	211 531
23	—	$\frac{12}{003}$	—	205	—	$\frac{2}{003}$	$\frac{2}{003}$ — $\frac{1003}{314}$ — $\frac{405}{102}$	319	319	$\frac{2}{003}$	—	$\frac{2}{003}$	—
24	—	003	008	405	405	407	—	—	—	121	—	121	—
25	405	—	—	—	—	—	$\frac{2}{156}$	$\frac{2}{104}$	—	319	—	319	—
26	—	502—531 402	001	—	402	—	—	—	213	$\frac{2}{001}$ — $\frac{1003}{531}$	—	$\frac{2}{001}$ — $\frac{1003}{531}$	—
27	—	101	—	001	121	—	$\frac{2}{001}$ — $\frac{201}{201}$	—	—	$\frac{2}{136}$ — $\frac{1001}{131}$	—	$\frac{2}{136}$ — $\frac{1001}{131}$	—
28	—	—	—	201 405	202	401	—	139	$\frac{2}{121}$ 310	—	104 137	—	104 137
29	—	—	—	—	502	—	104	—	001	001	161	001	161
30	—	—	$\frac{3}{402}$ — $\frac{140}{140}$	$\frac{2}{201}$	305	$\frac{2}{101}$ — $\frac{220}{220}$ — $\frac{15}{15}$	$\frac{2}{214}$	205	130	—	413	—	413
31	—	—	—	—	—	—	—	—	113	—	$\frac{2}{106}$	—	$\frac{2}{106}$
Together	12/15	15/41	19/29	15/19	17/18	26/39	21/34	18/33	31/66	17/25	28/48	21/28	21/28

This makes a total of 183 different kinds of possible failures in automatic block installations.

With the aid of this data, and taking the number of train movements (N) in a given period as a basis, it is possible to determine the different degrees of irregularity $\frac{G}{N}$ in relation to the number of failures or $\frac{F}{N}$ in relation to the number of stops occurring for a given number of train-signals (trains meeting a signal).

Table 5 shows the proportion of irregularities $\frac{G}{N}$ and $\frac{F}{N}$ recorded during

the operation of the automatic block for the years 1932, 1933, 1934 and 1935.

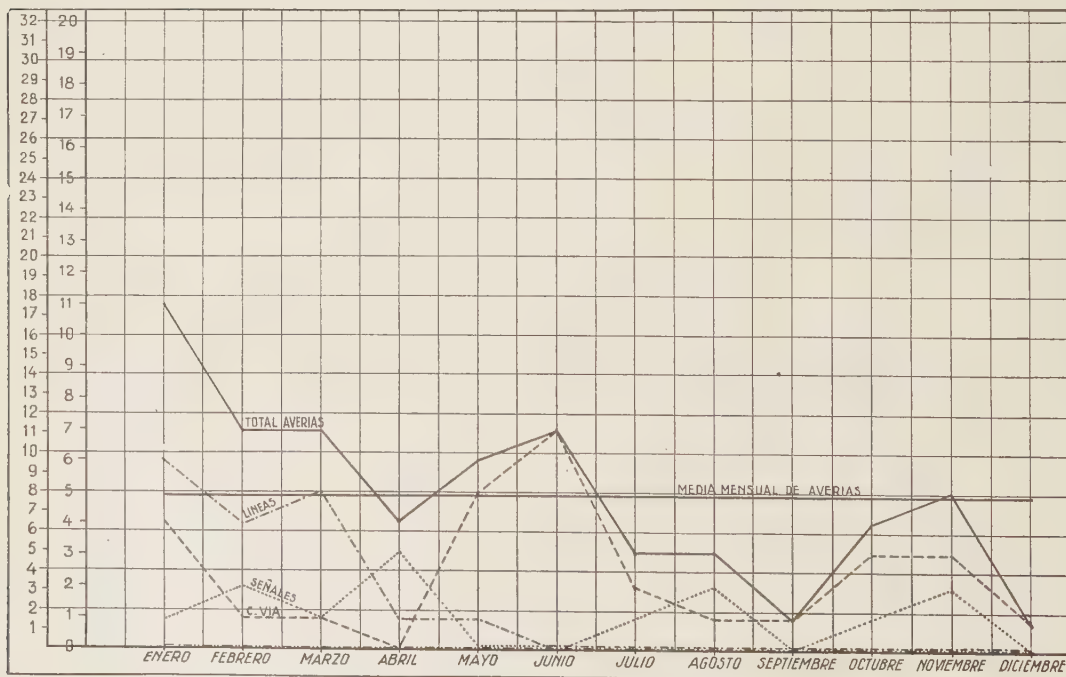
The figures for 1933 seem to refer to a normal year, and the increased number of failures in the following years, viz. 1934 and 1935, is entirely due to the large amount of workmen on the line, on account of the electrification work or the works which became necessary in order to increase the maximum speed, or on account of the alterations to the automatic block installations in view of the electrification.

In fact, the data for 1936 which are not yet complete, permit us to say that we returned to the 1933 figures, both

Block system on the Madrid-Villalba line. — 61 signals.

(Year 1935).

Percentage of
signal failures.
Failures.



Graph. 2. — Northern Railways of Spain.

Explanation: See graph 1.

for the $\frac{G}{N}$ and the $\frac{F}{N}$ proportions and it is hoped that these figures will still be improved in the future.

It must be noted, however, that the ratio of irregularity $\frac{G}{N}$ is approximately three failures to 10 000 train-signals.

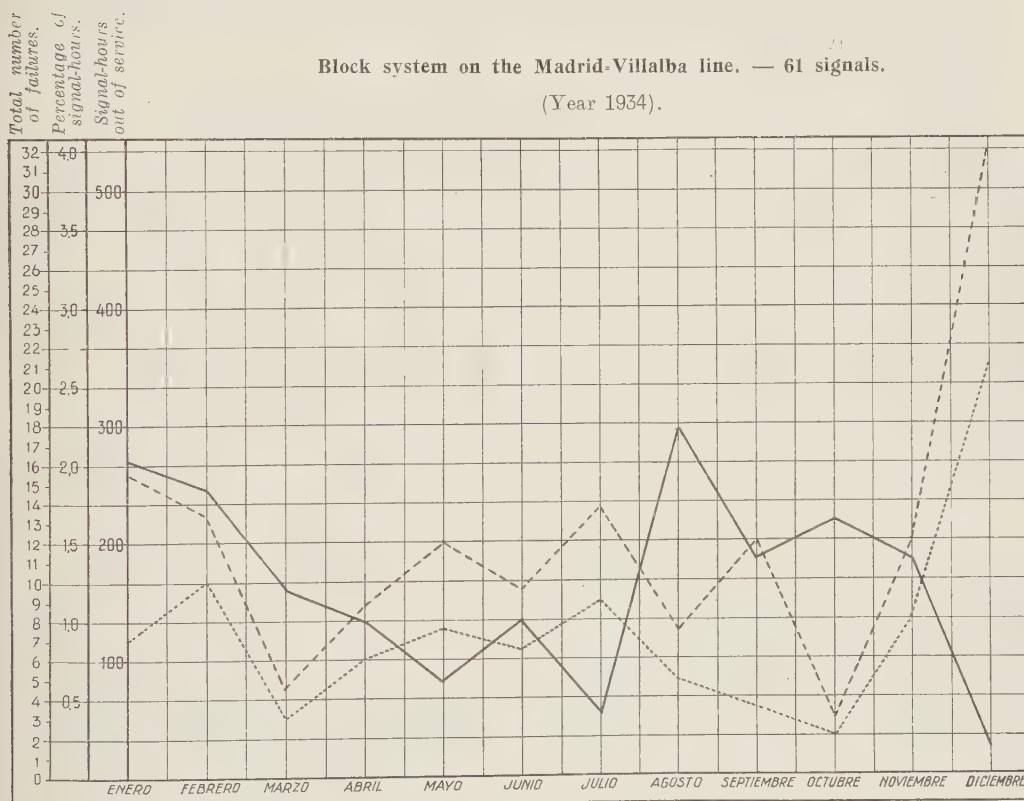
In this respect, it must be borne in mind that the average length of the automatic block sections on the Rome-Naples « Direttissima » is 5 500 m. (18 040'), and that consequently the setting at *danger* of a signal is governed

by any failure on the 5 or 6 track circuits and apparatus involved.

Furthermore, it should be added that among the conditions necessary to allow the setting to *line clear* of the signals on the above block installations, are the returning to danger of the preceding block signal and its lighting, as well as the de-energization of the relays. If therefore one refers to the number of failures per signal, a higher proportion of irregularities should be found than in automatic block signalling where the length of the block sections is less than approximately 1 100 to 1 300 m. (3 500' to 4 260'), each block section comprising

Block system on the Madrid-Villalba line. — 61 signals.

(Year 1934).



Graph. 1-b. — Northern Railways of Spain.

Explanation { Signal-hours out of service.
 { --- Percentage out of service.
 { — Total number of failures.

one track circuit only, and where the circuits are much simpler due to the absence of certain conditions.

On the contrary, lower figures will be found in the proportion of irregularity expressed by the number of failures per kilometre of single-track line equipped with the automatic block.

Table 8 shows that the number of danger aspects displayed untimely by signals is 1.36 per signal, while it goes up to 0.43 per track-kilometre equipped with automatic block signalling.

Conclusions.

The statistical data furnished by the various Railways cannot be compared

with each other, as they refer to different operating conditions.

It would be desirable to keep statistics of failures, giving the following information :

(a) Number of failures, i.e. untimely danger aspects per track-kilometre;

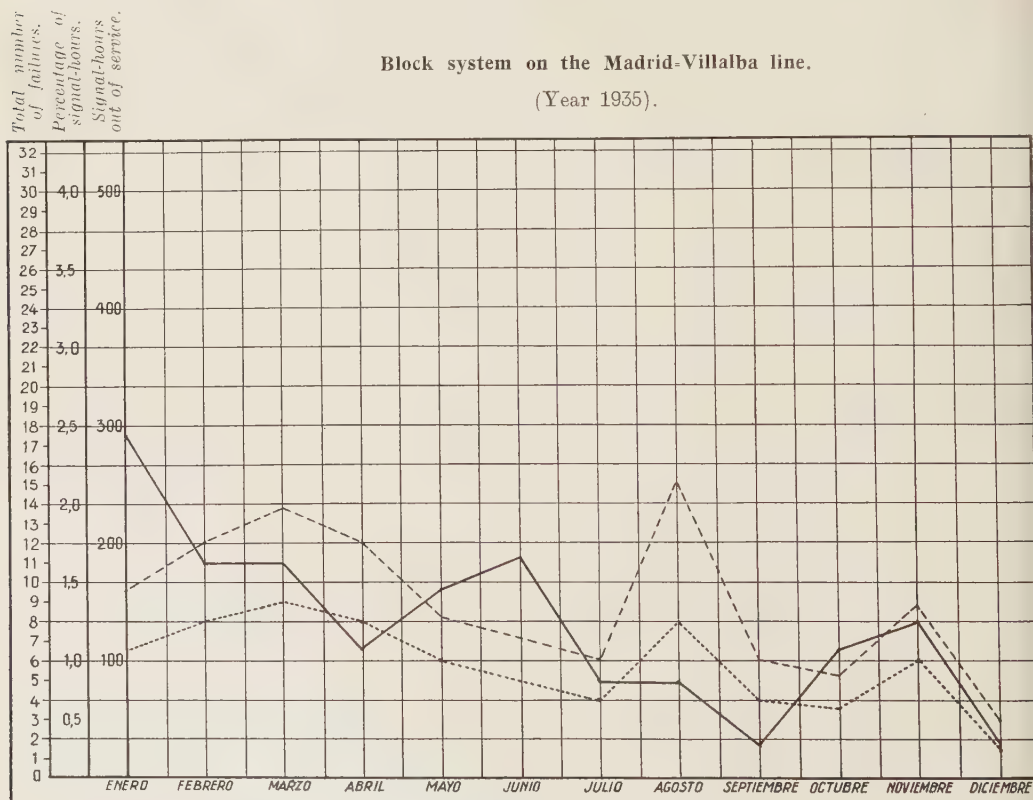
(b) Number of signal-hours out of service;

(c) Relation between the number of untimely danger aspects shown by signals and the number of train-kilometres;

(d) Relation between the number of signal-hours of failures (hours out of service) and the number of train-kilometres;

Block system on the Madrid-Villalba line.

(Year 1935).



Graph. 2-b. — Northern Railways of Spain.

Explanation: See Graph 1-b.

TABLE 5.

Automatic block of the Rome-Naples « Direttissima ».
Statistics of failures.

Year.	Number of train-signals. (N)	Number of failures. (G)	Number of stops. (F)	Proportion of irregularity.	
				G/N	F/N
1932	586 143	231	330	0.0003941	0.0005630
1933	814 536	240	395	0.0002946	0.0004849
1934	893 972	394	612	0.0004407	0.0006845
1935	987 661	500	792	0.0005163	0.0008020

TABLE 6.

Number of failures divided into groups and number of corresponding stops caused by these failures.

Year.	Groups of Failures.						Total of failures.	Ratio of number of failures to number of train stops.
	0	1 Relays.	2 Track.	3 Signals.	4 Stations.	5		
1932	$\frac{62}{134}$	$\frac{58}{67}$	$\frac{33}{37}$	$\frac{28}{32}$	$\frac{27}{32}$	$\frac{23}{28}$	$\frac{231}{330}$	1.42
1933	$\frac{61}{171}$	$\frac{60}{75}$	$\frac{34}{50}$	$\frac{27}{30}$	$\frac{36}{41}$	$\frac{22}{28}$	$\frac{240}{395}$	1.64
1934	$\frac{75}{169}$	$\frac{86}{130}$	$\frac{56}{76}$	$\frac{24}{40}$	$\frac{103}{131}$	$\frac{50}{66}$	$\frac{394}{612}$	1.55
1935	$\frac{116}{276}$	$\frac{94}{130}$	$\frac{48}{57}$	$\frac{36}{55}$	$\frac{162}{222}$	$\frac{44}{52}$	$\frac{500}{792}$	1.58

TABLE 7.

Automatic block on the Rome-Naples « Direttissima ».
Failures on the line and stops caused by same.

Years.	Number of signals. (S)	Number of failures. (G)	Ratio. G/S	Number of km. (K)	Ratio G/K
1932	176	231	1.31	550	0.42
1933	176	240	1.36	550	0.43
1934	176	394	2.23	550	0.71
1935	176	500	2.84	550	0.90

TABLE 8.

Number of failures per signal and per track-kilometre in automatic block signalling installations with long and short block sections (for a normal year).

	Long block sections with complicated circuits.	Short block sections with simple circuits.
Number of failures per signal	1.36	1
Number of failures per track-kilometre	0.43	0.83

(e) Relation between the number of train stops and the number of train-kilometres;

(f) Relation between the number of minutes during which trains are stopped and the number of train-kilometres.

Adjustment of track circuits and their operation under various climatic conditions; working difficulties caused by track maintenance work.

The causes which may prevent the track circuits from working properly are in connection with:

- (1) the condition of the insulation of the rail joints;
- (2) the earthing of the insulated rails by the track maintenance men;
- (3) the climatic conditions;
- (4) interruptions of the feed current.

(a) The *insulated joints* used by the *Italian State Rys.* and the *Northern Rys. of Spain* in automatic block signalling are of the well known Weber type. The former Administration is at present trying out a new type of wooden insulated joint, which — although it is still in the experimental stage — seems to give satisfactory results.

From the graphs 1 and 2 obtained from the *Northern Rys. of Spain* it appears that track-circuits are more

frequently damaged in summer than in winter. Defects reached the maximum of 7 in August 1934, against only one in May, June and July, two in January and February, three in April, September and October, four in November and none in December, 1934.

In 1935 the maximum number of failures was also 7 in June, against one in February, March, August, September and December, two in July, three in October and November, and four in January. Track circuit failures are due chiefly to rail expansion which causes the insulated joints to deteriorate.

(b) In order to avoid the earthing of the insulated rails in track circuits by the track maintainers, the appliances have been insulated (track gauges).

(c) No failures, however, can be traced to *unfavourable weather conditions*, such as snow, heavy rain, etc., because the track relay feed has been so adjusted that it is always sufficient to energize the relay.

Artificial lines have been used for this purpose, of several parts, each equivalent to 100 m. (328') of track as far as resistance, inductivity, capacity and conductivity to earth are concerned.

The perfect operation of the relays has thus been ensured between the two admitted limits due to variations in summer and winter, and the relays become

properly de-energized with a 1-ohm shunt.

(d) Finally, an endeavour has been made to provide against lack of feed current, by feeding the line itself in parallel from several sources, and against interruptions caused by the blowing out of fuses, by means of automatic circuit breakers.

14. Modifications to automatic block signalling installations on electrified lines.

A distinction must be made here between A. C. electrified lines (single-phase or three-phase) and D. C. lines.

The *Italian State Rys.* have automatic block installations on D. C. electrified lines; they employ six-phase mercury arc rectifiers giving a 300-cycle or 100-cycle peak current depending on whether the rectified A. C. is 50 or 16 2/3 cycles respectively. The amplitude of this current will not exceed 3 % of the value of the D. C. voltage.

The two lines with automatic block which have been electrified these last years, and which are fed with D. C., are: the Rome-Naples « *Direttissima* » — which was equipped with automatic block ever since it was opened with steam traction, and which was electrified in 1935 — and the Bologna-Florence « *Direttissima* » equipped with automatic block in 1934, when the line was put in service directly as an electrified line.

These two lines have 50-cycle A. C. track circuits and the 100-cycle A. C. has no effect on the relays.

When the Rome-Naples « *Direttissima* » was electrified, it was only necessary to add impedance bonds, as the track circuits were already fed from a 50-cycle alternating current source.

No anomaly has been discovered in the operation of these track circuits during one year after electrification.

15. Advantages of automatic block signalling.

Automatic block signalling installations present certain advantages over manual block installations, or block system by telegraphic messages. These advantages are:

- (a) safety of operation;
- (b) increased line capacity;
- (c) reduced working expenses.

The inquiries made on the subject prove that these installations increase the safety of operation compared with the telegraphic systems. If compared with manual block installations (where dangerous failures are always controlled by the action of man and cannot be ascertained if in addition to these failures there is one due to man himself), automatic block installations have the advantage of a high degree of safety, but only where these installations are such that the safety of operation can only be endangered by two or more simultaneous failures, as it is considered less likely to have two failures in two different devices than one failure in an apparatus and one failure due to man himself.

Even without taking into account the above considerations, automatic block must be considered necessary on all lines carrying heavy traffic, whereon the running of trains is so intense that it would be impossible to space them by the manual operations required with non-automatic block signalling.

On the other hand, the capacity of a line can be increased in a much larger proportion by automatic block than by manual block signalling.

From the point of view of working expenses, automatic block signalling is more economical as no personnel is required, while non-automatic block requires three men for each block section if trains run continuously or almost continuously.

However, maintenance charges for automatic block signalling are higher than for manual block signalling, as maintenance must be more accurate. Furthermore, the first cost is higher than for manual block signalling.

In order to appreciate the economic advantage offered by automatic block signalling compared with manual block, the following points should be confronted :

(1) interest and amortization of capital invested in the installation (A);

(2) annual expenditure on maintenance, staff and materials (B);
with

(1) interest and amortization of capital invested in the manual block installation (A');

(2) annual expenditure on maintenance, staff and materials (B');

(3) annual working expenses (C).

Generally $A > A'$ and $B > B'$, and consequently $A + B > A' + B'$.

To obtain an economic advantage from the automatic block, one should have :

$$D < C$$

assuming

$$D = (A + B) - (A' + B').$$

In the first place, this formula indicates that it is not always possible to say whether, from an economic point of view, it is desirable to have manual block or automatic block. It shows, however :

(1) that automatic block signalling is not to be recommended, from an economic point of view, if between consecutive stations with pointsmen and signal boxes there is only one block section;

(2) that the possibility of an economic advantage over manual block increases with the number of intermediate boxes and, therefore, with the number

of block sections necessary between stations.

We will close this chapter with the following conclusions :

Automatic block signalling always presents advantages over other systems from a safety standpoint. It also allows the highest possible increase in the capacity of the line.

Under certain favourable conditions, automatic block signalling can also present economic advantages.

It is hoped that the Railways will before long apply this modern system to their lines and thus contribute to the development of traffic and improvement of general operating conditions.

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* * *

Information on signalling installation on the Italian State Railways.

After examining the questions relating to automatic block signalling, and before dealing with the power signal boxes, we give some information about the development of signalling on the *Italian State Rys.* and the goal they shortly hope to reach with regard to economic and financial possibilities.

At present, signalling on the *Italian State Rys.* is carried out :

(a) *on standard-gauge lines carrying light traffic :*

by means of so-called second-class signals;

(b) *on other lines :*

by means of what is called « double signalling », i.e. a main signal preceded by a distant signal.

After an agreement was arrived at between the Operating, Mechanical and Permanent-Way Departments, and after close examination of the question, the minimum distance between the main signal (first-class signal) and the distant signal were decided. The following

two factors were taken into consideration :

(a) Maximum speed allowed on the line;

(b) Gradients.

These distances are shown in the following table :

Maximum speed allowed on the line.	Distance between distant signal and main signal.		
	On lines with 1 in 100 and steeper gradients.	On lines on the level or having 1 in 100 to 1 in 200 gradients.	On lines having gradients steeper than 1 in 200
Equal to or less than 70 km. (40.4 miles) per hour	400 m. (1312')	700 m. (2296')	1000 m. (3280')
Equal to or higher than 90 km. (56 miles) per hour, but not excee- ding 120 km. (75 miles) per hour.	800 m. (2624')	1000 m. (3280')	1200 m. (3937')

There exist now three types of so-called « double signalling », according to the type of signal used for the main signal :

(1) « Double signalling » with first-class signals mounted on double brackets;

(2) « Double signalling » with first-class signals, carrying several superimposed arms;

(3) « Double signalling » with first-class signals, carrying a single arm.

The installations grouped under (2) and (3) will be replaced by installations as described under (1), either when modifications are carried out or when a favourable opportunity arises and the necessary funds are available to make such replacements.

It has been decided, therefore, that the new installations on lines where the speed reaches and exceeds 90 km. (56 miles) per hour, will be of the first type, i.e. with signals mounted on double brackets.

In order to allow the engine driver to recognize from a distance the position and the indications of the main signal,

the distant signal preceding this main signal will also be mounted on a double bracket.

The meaning and indications of the double bracket type signal have been improved in the last few years, and it has been decided to consider this signal : either as a *topographic* or a *route signal*, as it can indicate that the route corresponding to the arm or the colour light giving the *line clear* indication, is to the left, or else to the right of other routes, or as a *speed* signal, as it can indicate that the route corresponding to the arm or the colour light giving the *line clear* indication, must be run through at a speed not exceeding 30 km. (18.6 miles) per hour (if the colour light or the arm are low down), or else at the maximum speed allowed on the line and specified in the service time-table (if the light or the arm are high up).

By adopting the principles that the highest semaphore blade or colour light of a signal mounted on a double bracket allows the maximum speed permitted on the line, one eliminates the other idea

adopted up to the present that the *direct route* is the only condition for accepting an upper arm or upper light on a double bracket signal. The official regulations (regulations on signal operation, regulations on train operation, traffic regulations) have recently (1935) decided that a low arm or low colour light giving the line clear indication should allow the maximum speed of 30 km. (18.6 miles) per hour.

The regulations lay down that a train normally received on the route which can be run over at the maximum speed, must be advised if for some reason it must be received on another route, which cannot be passed at that speed.

It has been decided, as a modification to this provision, that this warning must not be given if there is an absolute stop signal mounted on a double bracket preceded by a distant double-bracket signal.

In fact, article 48 of the regulations on signal operation lays down that the trains admitted to a station by a low arm giving the line clear indication and with the distant arm of the starter signal in the *danger* position, must always consider themselves as accepted on a dead end track, or an occupied track section.

While the *topographical* indications displayed by the double bracket signal are very clear by themselves, the speed indications are not sufficient with regard to neither possibilities offered by the line nor the traffic requirements in general.

The speed indications must therefore be completed by others given in the service timetable and in some exceptional cases by special instructions for each train.

As stated above, the high signal arm or light authorizes the engine driver to proceed without any speed restriction. Such restriction, however, is imposed by the maximum speed allowed on the part of the line beyond the signal, such speed

being indicated in the working timetables.

This being so, the indication of maximum speed given by the high arm or light of a double bracket signal must not be restricted by prescriptions or remarks in the working timetables, as in this case a possible non-observation of the regulations by the engine driver might cause the train to proceed at a *higher* speed than that allowed, and thus endanger safety.

On the other hand, the maximum speed indicated by a low arm or light of a double bracket signal displaying the *line clear* indication (30 km. per hour) may be increased by a remark in the working timetables, which may allow the train to proceed at a speed higher than 30 km. per hour but lower than the maximum speed permitted beyond the signal.

Such an increase in speed prescribed for a low arm or light on a double bracket signal is not dangerous, because the consequence of a possible non-observation of the regulation will be a lower speed than the maximum allowed.

Instructions have been printed in this connection, giving examples of the less simple cases which may occur in practice, to serve as a rule to be observed by the signal department, when installing signalling plant.

* * *

PART TWO.

Power-operated signal boxes.

1. Foreword.

The objects of this Second Part are :

(a) Power boxes, i.e. signalling plant in which points and signals are operated by means other than the muscular effort of the signalman;

(b) Remote control of points and signals;

(c) Automatic train control.

Replies were received from the following Administrations :

- (1) Italian State Rys.;
- (2) Bern-Lötschberg-Simplon Rys. (Switzerland);
- (3) Portuguese Rys. Co.;
- (4) Rumanian State Rys.;
- (5) Northern Rys. of Spain;
- (6) Egyptian State Rys.

All these Railways only own power boxes as defined above i.e. have neither installations for controlling signals from very long distances nor automatic control.

* * *

CHAPTER I.

2. Statistical data.

Table 1 below shows the number of power plants in service in 1935 on the various Railways, including electric, hydraulic, electro-pneumatic, etc. boxes.

Table 2 gives the relation between the length of lines of each Railway and the number of power boxes, and the relation of the latter to the total number of interlocking plants.

Table 1 shows that the Railways which have answered our questionnaire only have a small number of power boxes, with the exception of the *Italian State Rys.*, who on 30th June 1936 had 577 power boxes in service.

Table 2 shows that the number of power boxes in relation to the total number of route-kilometres varies between a maximum of 0.035 on the *Italian State Rys.* and a minimum of 0.0007 on the *Portuguese Rys. Co.*, while the number of power boxes in relation to the number of interlocking plants varies between a maximum of 0.31 on the *Italian State Rys.*, and a minimum of 0.0025 on the *Rumanian State Rys.*

* * *

Before going into any details, and in order to make the rest of this report more understandable, we are giving below the principles adopted by the *Italian State Railways* when studying their signalling circuits.

The signal circuits and the circuits of the central interlocking plants are designed in such a manner that failures between the conductors react on the safety side.

An attempt has also been made to obtain protection against faults due to two simultaneous failures.

In consequence, it has been decided that the signal circuits be provided with:

- (1) Single break;
- (2) Double or multiple break;
- (3) Double or multiple break and neutral safety track circuit normally closed « chiuso neutro di sicurezza », or c. c. n.).

The single break is only allowed in circuits located entirely in the power boxes and which have to give indications or control the operations carried out by the staff, i.e. in the circuits governing the control apparatus.

The double or multiple break, i.e. the break of all the line wires and circuits even those entirely in the cabin affecting safety of operation, is compulsory.

Finally, the double or multiple break and the « c. c. n. » are compulsory in track circuits located outside the signal box and affecting the safety of operation.

It must be noted in this connection that this circuit arrangement is called closed neutral safety circuit, and not safety short-circuit, due to the fact that in some cases its resistance is not negligible.

As a rule, the single break does not protect the operation of the apparatus when there is a contact between the part of a conductor interrupted by a contact breakage up the line and the part down the line past the interruption,

TABLE 1.

Power signal boxes in service at the end of 1935.

RAILWAYS.	Number of power boxes.				
	Electric.	Electro-pneumatic.	Electro-mechanical.	Hydraulic.	Total.
1. <i>Italian State</i>	131	...	...	446	577
2. <i>Bern-Lötschberg-Simplon.</i>	1	1	9	...	11
3. <i>Rumanian State</i> . . .	3	...	...	...	3
4. <i>Northern of Spain</i> . .	2	...	...	1	3
5. <i>Portuguese Rys Co.</i> . .	...	...	2	...	2
6. <i>Egyptian State.</i> . . .	...	3	...	...	3

which can re-establish the faulty condition. This is the reason why it is only admitted in the circuits which do not affect safety.

The double or multiple break protects the operation of the apparatus fed, whatever the single failure in the circuit may be, earthing, breaks, contacts,

and even if two failures occur simultaneously (two earths, two breaks, one earth and one contact, one earth and one break, one contact and one break). There is only one case (double contact, arranged and becoming separated) where it is not possible to obtain a protection through the double break, but

TABLE 2.

RAILWAYS.	Length of lines, km.	Total number of interlocking plants.	Ratio of	
			Number of power boxes to length of lines (km.).	Number of power boxes to number of interlocking plants.
1. <i>Italian State</i>	16 297	1 863	0.035	0.31
2. <i>Bern-Lötschberg-Simplon.</i>	...	...	0.004	0.0344
3. <i>Rumanian State</i> . . .	11 206	1 261	0.00026	0.0025
4. <i>Northern of Spain</i> . .	3 811	...	0.0008	0.025
5. <i>Portuguese Rys Co.</i> . .	2 486	9	0.0007	0.22
6. <i>Egyptian State.</i> . . .	...	...	...	...

it is difficult for such occurrence to materialize, and it must be considered impossible in well made installations, when the conductors are located only in the signal box.

The third degree of safety, i.e. the protection of the auxiliary apparatus by means of the « c. c. n. » protects against two kinds of failures, provided of course that certain precautions have been taken, which need not be gone into in the present report.

The advantages which it is hoped to obtain by the adoption of the closed safety circuit are not limited to the fact that the installations are protected against two failures on the same line with two conductors, as such an arrangement can and does actually facilitate the determination of the minimum insulation resistance values required in the wiring of a power installation and, therefore, the sensitivity required in an « earth » indicator can be exactly predetermined.

The detection of insulation failures is made easier due to the fact that all the apparatus and mechanisms on the ground are normally cut off from the source of operating energy, while the controls circuits of the signals and points are continuously fed. When these insulation failures occur it is easy to tell if the faulty line is an operating or a control line.

3. Arrangements designed to reduce the number of levers.

None of the above Railways have power boxes with route levers, i.e. signal boxes in which a single lever is operated for the control of various apparatus involved in the setting up of a route, with the exception of the *Northern of Spain* which has an electro-hydraulic box with M. D. M. control, supplied by Messrs Aster, and installed in the Principe Pio station, Madrid.

On the *Italian State* as well as on the

Egyptian State Rys., arrangements are used to reduce the number of levers, designed so that a single lever can operate several signals giving access to one track, and that the control of the signals be selected automatically by the position of the points.

An example of the application of this arrangement in power boxes is given by the station installations on single track (fig. 1).

The protection signals (A, B, C) of this station governing trains arriving from X and received on tracks III, II, I, respectively, are operated by 3 three-position levers.

These levers set the signals at *line clear*, for instance, when they are reversed in the forward position. In the backward position they set the starting signals of tracks III, II and I (A', B', C') at *line clear*.

The protection signals D, E, F, from Y governing trains arriving on tracks I, II, III and the corresponding starting signals D', E', F', for trains leaving the three tracks for Y are operated in a similar way.

It has thus been possible to economize the levers and mechanical interlockings which would have been required had the signal pairs A A', B B', C C', D D', E E', F F' been operated by two different levers.

Contrariwise, several levers are often used for several routes, governed by one signal, particularly if these signals govern shunting movements. This is often the case in large stations where the complete routes between the station track and the open track are divided into several sections which are limited by « points ». At each « point » low signals are located which govern the movements beginning from the « point » which is considered in both directions.

Indicating levers are used for interlocking the point levers in the desired position.

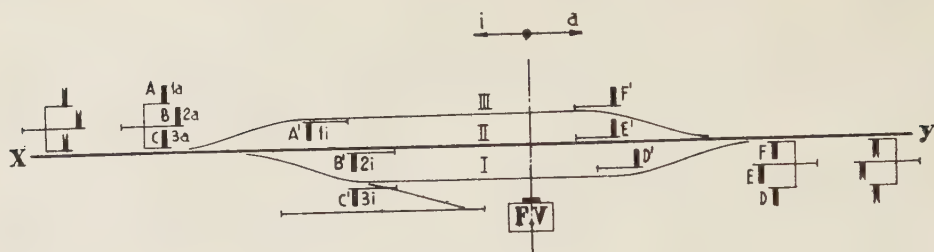


Fig. 1.

Thus, in figure 2 for instance the twelve routes possible between A, B, C and X, Y, Z and U are made up by seven sections obtained by cutting the twelve routes : AX, AY, AZ, AU, BX, BY, BZ, BU, CX, CY, CZ, CU at « M ».

Route levers 1, 2, 3 will be used for the movements between A, B, C and M, and levers 4, 5, 6, 7, for the movements between M and X, Y, Z, U.

Assuming that these route levers are three-position levers, it will be possible with these same levers not only to mechanically interlock the points of each route in the desired position, but also to set at *line clear* the low signals, *a*, *b*, *c*, starters from A, B and C towards M, and

m', starter from M towards *a*, *b*, *c*, and low signals *x*, *y*, *z*, *u*, starters from X, Y, Z and U towards M, and signal *m*, starter from M towards X, Y, Z, U.

In this case, signal *a* will be controlled by lever 1*a*, signal *b* by lever 2*a*, signal *c* by lever 3*a*, while signal *m'* will be controlled by levers 1*i*, 2*i* or 3*i* according to the route set, viz. (MA), (MB) or (MC).

Similarly, signal *x* will be controlled by lever 4*i*, signal *y* will be controlled by lever 5*i*, signal *z* will be controlled by lever 6*i*, signal *u* will be controlled by lever 7*i*, while signal *m* will be controlled by levers 4*a*, 5*a*, 6*a* or 7*a*, according to the

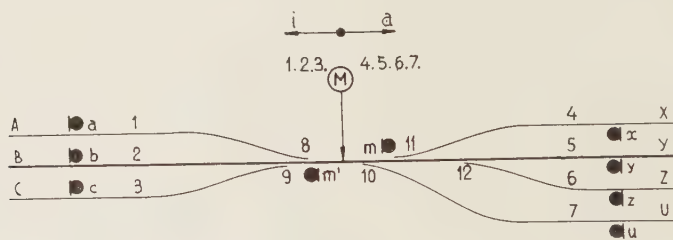


Fig. 2.

route set, viz. (XM), (YM), (ZM) or (UM).

It is obvious that for going from A to U, the two routes (AM) and (MU) will have to be set, i. e. it will be necessary to reverse levers 1*a* and 7*a* — after having placed the point levers in the desired position — which levers 1*a* and 7*a* set to *line clear* signals « *a* » and « *m* », and interlock and lock in the

position corresponding to the forbidden track section (danger) the other conflicting signals *b*, *c*, *m'*, *x*, *y*, *z*.

The operation by means of the four levers 4*a*, 5*a*, 6*a*, and 7*a* of signal *m* can be carried out as indicated in figure 3, when the double break and the *safety* « c. c. n. » are used.

If it is desired to make the setting at *line clear* of signal *m* dependent on the

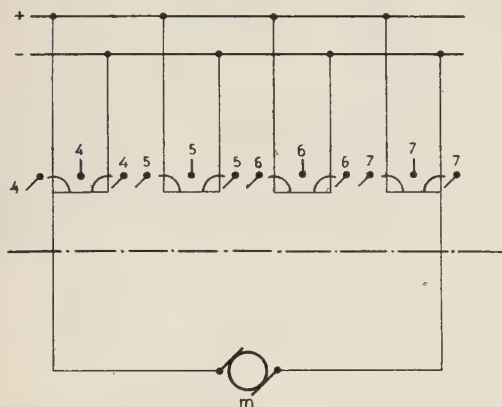


Fig. 3.

condition that electric point locking on the route concerned subsists, there will be added on the contact lever ahead of signal *m* (4a, 5a, 6a, 7a), the condition of a normal energized or reversed control relay.

For instance, the conditions of points 10 and 11 will be placed on the controlling shaft of lever 4 (route MX).

The conditions of points 10, 11 and 12 will be placed on the controlling shaft of lever 5 (route MY).

The conditions of points 10, 11, 12 will be placed on the controlling shaft of lever 6 (route MZ).

Finally, the condition of point 10 will be placed on the controlling shaft of lever 7 (route MU).

The diagram, figure 3, will become that of figure 4 which can be further simplified, as shown in figure 5, by introducing the arrangement of double break and a safety short-circuit.

If for the arrangement shown in figure 2 the intermediate point M had not been provided, 12 route levers would have been required to control the seven low signals *a*, *b*, *c*, *x*, *y*, *z*, *u*, in order to go from one side of the twelve routes to the other (fig. 6).

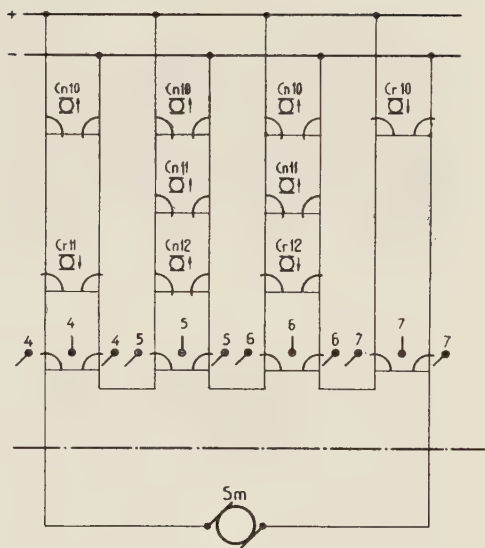


Fig. 4.

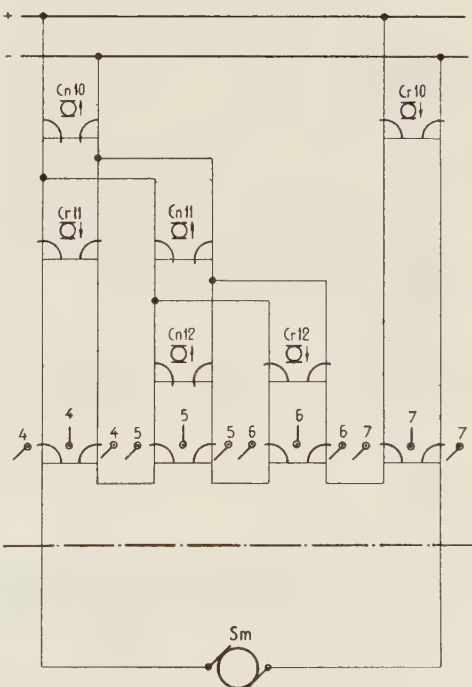


Fig. 5.

If routes (AX), (AY), (AZ), (AU) and their opposing routes are set respectively by levers 1, 2, 3 and 4 routes (BX), (BY), (BZ), (BU), and their opposing routes set by levers 5, 6, 7 and 8, and routes (CX), (CY), (CZ), (CU) and their opposing routes by levers 10, 11, 12, 13, signal *a* will be set in the *line clear* position by levers 1, 2, 3, and 4 when

they are reversed in the forward position; signal *b* will be set at *line clear* by levers 5, 6, 7 and 8, when they are reversed in the forward position, and signal *c* will go to the *line clear* position by levers 9, 10, 11 and 12 when they are reversed in the forward position.

The same applies to the other oppos-

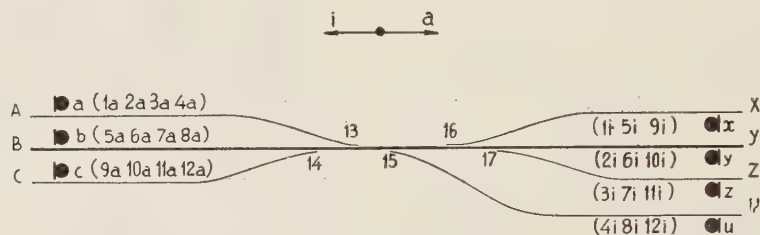


Fig. 6.

ing routes controlled by signals *x*, *y*, *z* and *u*.

Signal *x* will be set in the *line clear* position by levers 1, 5 and 9 when reversed in the backward position; signal *y* will go to *line clear* when levers 2, 6, and 10 are reversed in the backward position; signal *z* will go to *line clear* when levers 3, 7, and 11 are reversed in the backward position, and finally, signal *u* will be go to *line clear* when levers 4, 8 and 12 are reversed in the backward position.

In this case there will be 12 route levers instead of 7 as in the preceding case; but on the other hand there will only be seven signals instead of nine.

Finally, in this latter case, it will only be necessary to operate one lever per complete route while in the former case it is necessary to operate two. It would have been possible to proceed in a third manner, i.e. to set the various routes between A, B, C and M through one lever only, lever 1, figure 7, and the routes between M and X, Y, Z through another lever 2 by using somewhat more complicated interlocking than in the preceding case.

It would have been possible, in fact, to obtain the following interlockings between route and signal levers 1a, 2a, 1i, 2i, and point levers 21, 22, 23, 24 and 25 :

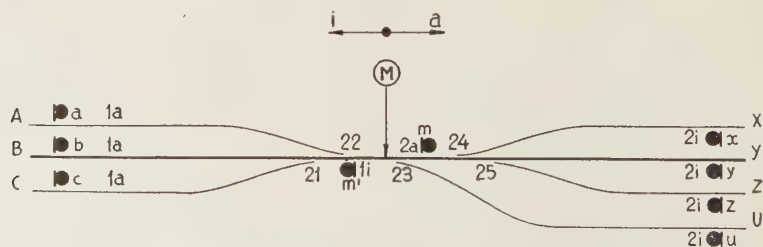


Fig. 7.

1a requires 2i	[(22 21) or (22 21 21)]
1i »	[(22 21) or (22 21 21)]
2a »	[(25 23 24) or (24 23) or (25 24 23) or 23]
2i »	[(25 23 24) or (24 23) or (25 24 23) or 23]

If the control table system permits mechanical interlocking between point levers, the above interlocking table may be substituted by a more simple one as given below :

1a requires	2i (21 21 22 22)
1i »	21 21 22 22
2a »	23 23 24 24 25 25
2i »	23 23 24 24 25 25
21 »	
22 »	21
23 »	
24 »	23
25 »	23 24

This being so, it is necessary to adapt the arrangement figure 8, to the operation of signals *a*, *b*, *c*, the arrangement of figure 9 to the operation of signal *m'*, and other similar arrangements to the operation of signals *x*, *y*, *z* and *u* and signal *m*.

These diagrams are converted into those shown in figures 10 and 11, respectively, when it is desired to use the double break arrangement and neutral safety short-circuit.

A greater economy is possible by omitting signals *m'* and *m* (fig. 12). In this case the lever interlocking will be as follows :

1a requires 2a	(21 21 22 22)
1i »	(21 21 22 22)
2a »	1i (23 23 24 24 25 25)
2i »	(23 23 24 24 25 25)
21 »	22
22 »	
23 »	
24 »	23
25 »	23 24

which is not difficult to carry out.

On the other hand, the operating circuits of signals *a*, *b*, *c* and *x*, *y*, *z* and *u*, represented by figures 13 and 14 are

more complicated than the preceding circuits, especially where it is desired to have double break and neutral safety short-circuit arrangements, because a large number of interruptions and contacts in the point locking relays will be required.

Figure 15 represents, in fact, the operating diagram of signal *a* with such an arrangement. The operating circuits of the other signals *b* and *c* will be similar, as in the case of the operating circuits of signals *x*, *y*, *z* and *u*.

Still more can be done by using a single three-position lever to operate the seven signals *a*, *b*, *c*, *x*, *y*, *z*, *u* (fig. 16).

The lever interlockings to be made in this case are as follows :

1a requires	21 21 22 22 23 23 24 24 25 25
1i »	21 21 22 22 23 23 24 24 25 25
21 »	22
22 »	
23 »	
24 »	23
25 »	23 24

and the operating circuits remain the same as in figures 13 and 14 showing

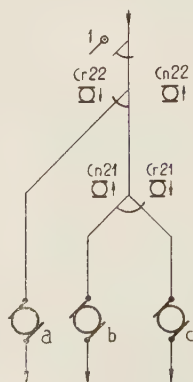


Fig. 8.

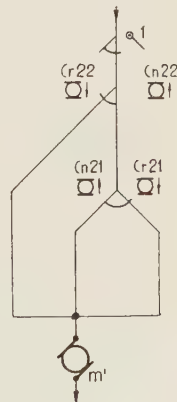


Fig. 9.

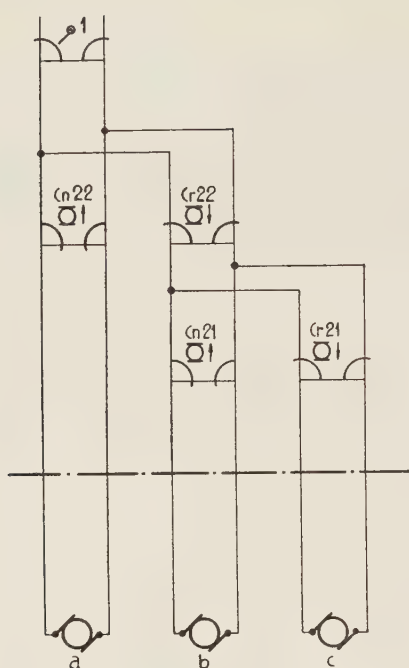


Fig. 10.

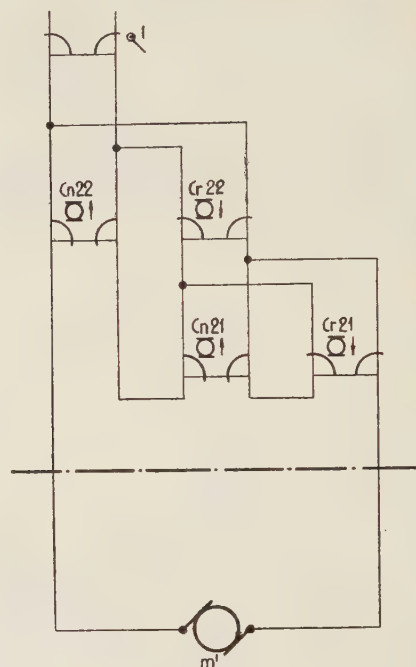


Fig. 11.

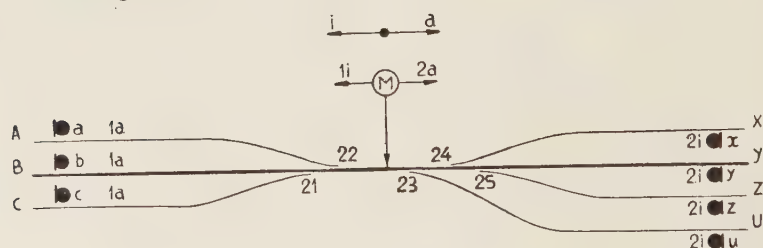


Fig. 12.

the method of operation for signal groups *a*, *b*, *c* and *x*, *y*, *z* and *u*, respectively.

The number of contacts necessary to apply the double break and safety neutral short-circuit arrangement to this case becomes very large, because it is necessary to repeat three times the arrangement shown in figure 17-A, and 4 times the arrangement B (fig. 18). This proves that the signalling as shown in figure 2 can be operated :

- (a) By means of 12 levers;
- (b) By means of 7 levers;
- (c) By means of 2 levers;
- (d) By means of a single lever.

The distribution of the contacts of the control relays to be used is shown in Table 3, applying to the three cases :

- (1) Single break (s. b.);
- (2) Double break (d. b.);
- (3) Double break and « c. c. n. » arrangement.

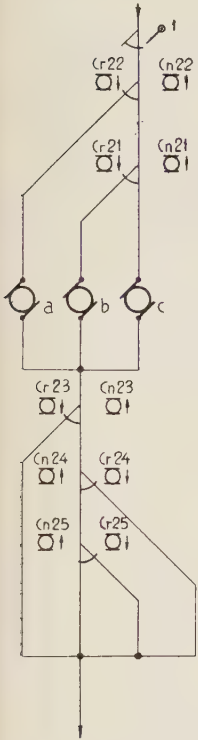


Fig. 13.

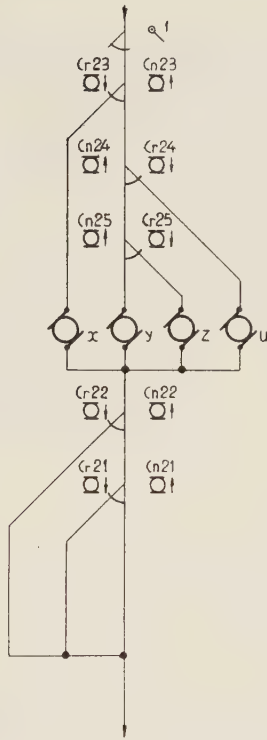


Fig. 14.

The conclusion is that if circuits are set up using a single break, no advantage is obtained from the point of view of economy, both with regard to initial cost and maintenance, by using several levers instead of one only, but if the circuits are made using the c. c. n. arrangement, the seven-lever solution must be used if a small number of contacts is wanted.

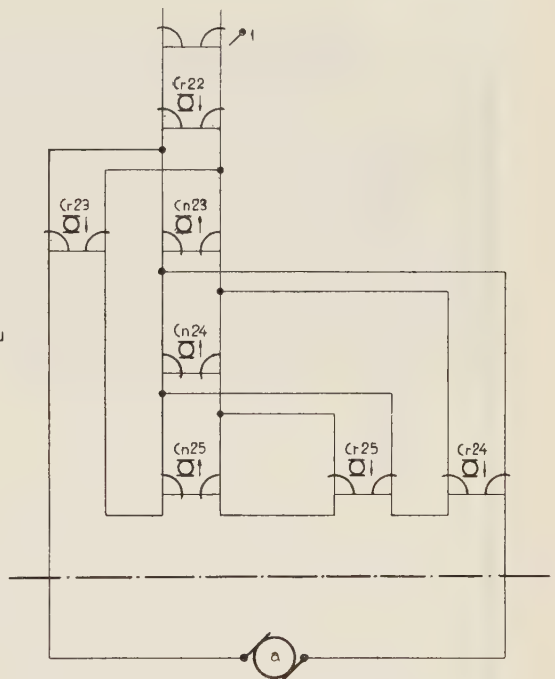


Fig. 15.

It is therefore impossible to state definitely which of the two arrangements is better: whether it is the operation of various conflicting signals through one lever, or through various levers. The first solution may however be considered more convenient.

Conclusion.

The arrangements designed to reduce the number of levers in the power boxes, although they might be of advantage in

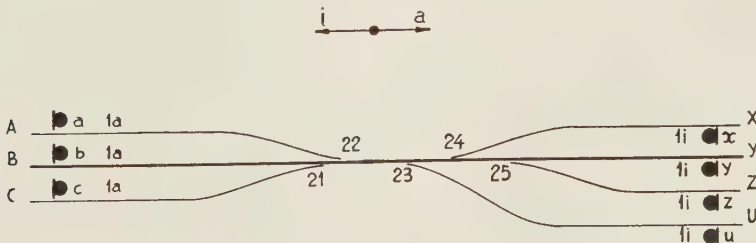


Fig. 16.

TABLE 3.

CASE.	Commutators of the relays controlling the points					
	21	22	23	24	25	
I (12 levers).	2	2	2	2	2	s. b.
	4	4	4	4	4	d. b.
	8	8	8	8	8	c. c. n.
II (7 levers).	2	2	2	2	2	s. b.
	4	4	4	4	4	d. b.
	8	8	8	8	8	c. c. n.
III (2 levers).	2	2	2	2	2	s. b.
	4	4	4	4	4	d. b.
	20	20	16	16	16	c. c. n.
IV (1 lever).	2	2	2	2	2	s. b.
	4	4	4	4	4	d. b.
	20	20	16	16	16	c. c. n.

some cases, do not always give satisfactory results in practice, due to the complicated track circuits, which sometimes make the location of failures difficult. At present, simple circuits are much preferred, not only to make the installation less complicated, but also to obtain a greater uniformity and better detection of earths which may occur in the installations.

This much increases the safety and regularity of operation. It is better, in our opinion to have a large number of simple and uniform circuits, than a small number of complicated circuits of various kinds.

4. Form of levers.

The opinions of the various Railways vary considerably on this point.

Thus the *Egyptian State Rys.*, for instance, say that the normal shape of lever has always given satisfactory results; the *Löetschberg Ry.* prefers the push-button system. The *Northern of Spain* prefers the C. T. C. type switch, while the *Portuguese Rys.* use both hand-levers and levers.

In practically all their boxes, the *Italian State Rys.* use normally shaped levers varying in size.

Levers in hydraulically-operated boxes are larger than those in electric boxes; ten years of experience have proved that electric levers should be stronger. In fact the new types designed by the *Italian State Rys.* are somewhat larger. It is hoped that this precaution will ensure a longer life of the mechanism,

especially where many movements are involved.

In order to effect savings, the *Italian State Rys.* have installed composite power boxes, in which the colour light and semaphore signals are operated electrically, while the points are operated manually a key locking system being used in addition.

To interlock the signal with the points, central locks with hand-levers operating the signals are used. They are two or three-position hand-levers and appear to give good results.

* * *

CHAPTER II.

5. Lever interlocking.

It is well known that one of the features and advantages of interlocking frames is that a signal cannot be set at *line clear* unless the points have been set for the corresponding route.

There is, therefore, an established sequence of lever movements, in a signal box — power-operated or not — to allow the passing, departure or arrival of a train in the territory governed by the box.

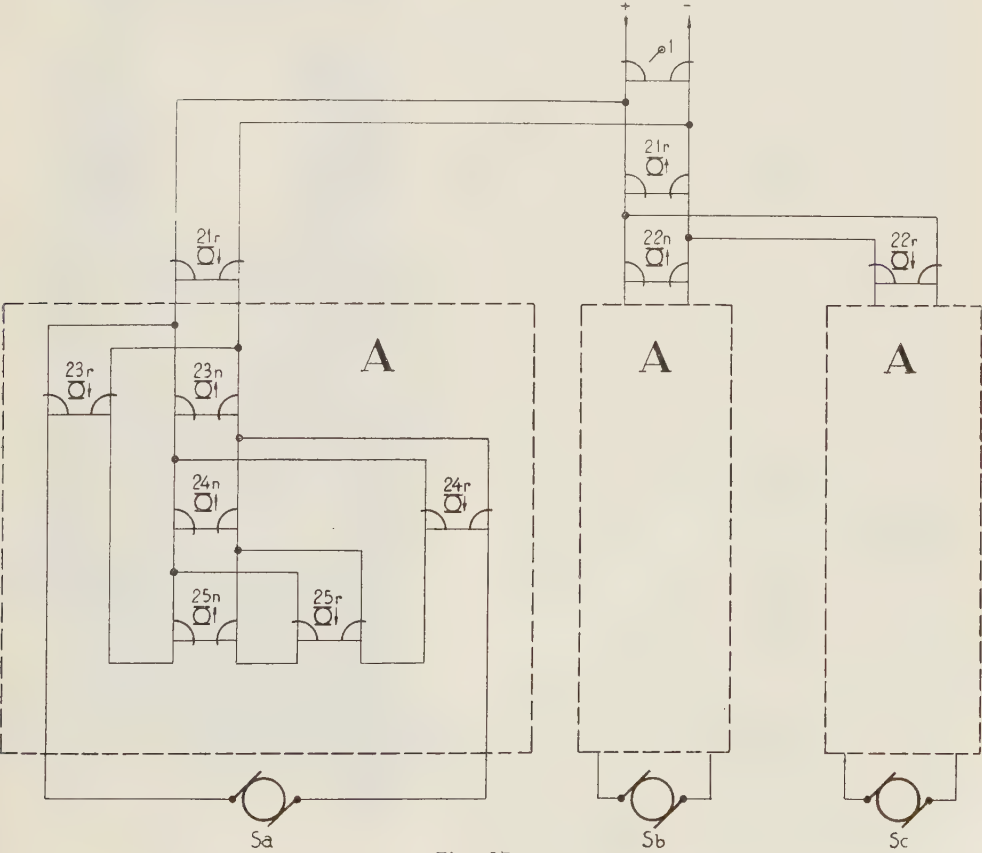


Fig. 17.

This sequence is obtained and controlled either through interlocking between levers, or through purely electric interlocking consisting essentially in breaking the operating circuits of the different apparatus involved (signals, points) which must not be operated, and this is quite independent from the operation of the levers themselves.

In this case, the levers are not interlocked. It may be said, therefore, that interlocking can be obtained by acting the operating levers :

(a) To establish a given order in which they have to be operated;

(b) In such a manner as to obviate the necessity of sequential operation;

(c) In a composite manner.

Interlocking obtained through the medium of the levers is either mechanical or electro-mechanical; the other, which is obtained without having to make the operation of the levers dependent on them, is purely electrical, as stated above.

The *Egyptian State Rys.*, *Lötschberg Ry.*, *Rumanian State Rys.* and *Portuguese Rys. Co.* use mechanical interlocking only, while the *Northern of Spain Rys.*,

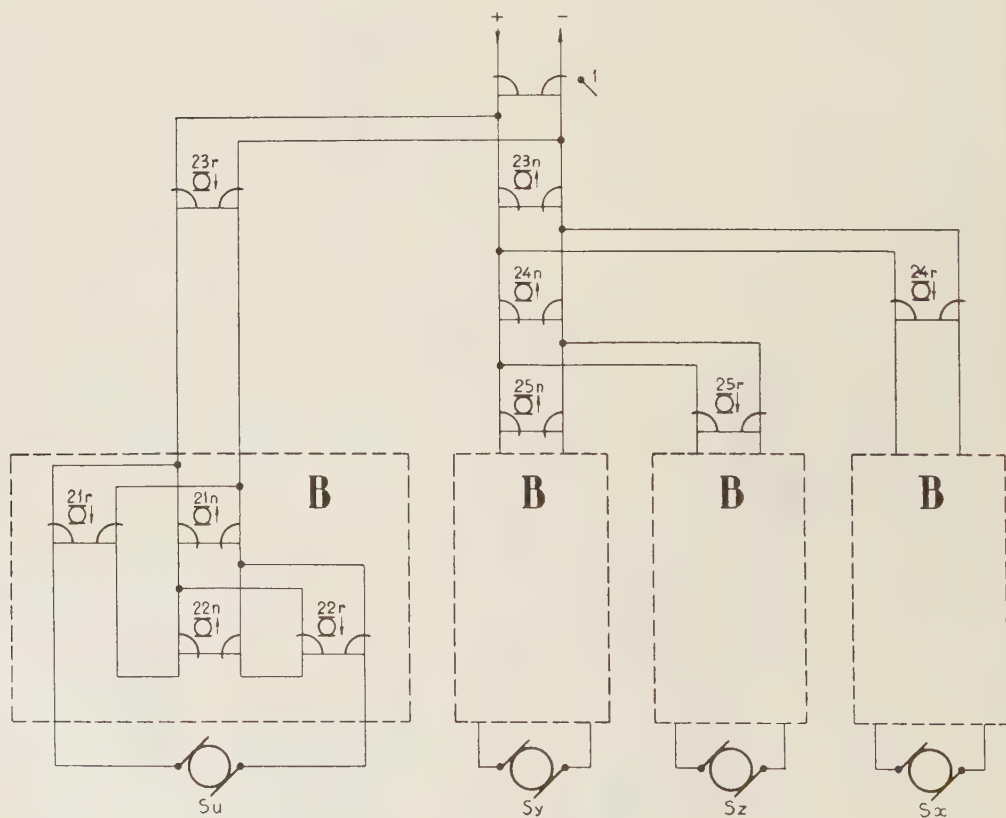


Fig. 18.

in a recent installation completed in the Barcelona station, use electro-mechanical interlocking by means of a bolt which locks the control lever, and by means of relays acting on the operating relays.

The *Italian State Rys.* use mostly mechanical interlocking in their power boxes, and it is the only type of interlocking used in their hydro-electric cabins, electro-mechanical lever inter-

locking being used only in those special cases where it is necessary to make a lever in one box dependent on a lever in another box. Electro-mechanical interlocking devices and contact combinators are applied to the levers which must be remotely interlocked.

In electric power boxes, lever interlocking is carried out either electrically or mechanically, or electro-mechanically, but the principle of the interlocking is always of a mechanical nature, so that for the most important movements, the mechanical interlocking is completed or repeated by electrical or electro-mechanical interlocking.

Sometimes it is possible to save electrical or mechanical interlockings when using three-position signal levers, for instance by using the same lever in one of the reversed positions (for example, forward or to the right) to operate a signal A, and in the other reversed position (for instance backward or to the left) — to operate another signal B, signal A giving access to track II to trains approaching from X, and signal B being the starter signal from track II towards X (fig. 20).

On the other hand, the interlocking of two stop or starter signals A and B, which give access to the same track, but are controlled by two different levers, is obtained mechanically by means of the point lever S (fig. 21).

In more complicated cases, the signals are interlocked with the points by means of indicating levers (interlocking the point levers of a route or part of a route).

The type of mechanical interlocking which is mostly used on the *Italian State Rys.* is the Stevens type, although other types are used as well in power boxes of the A. E. G. type.

While as a rule point levers and signal levers are interlocked mechanically, either directly, or through indicating levers (in complicated cases),

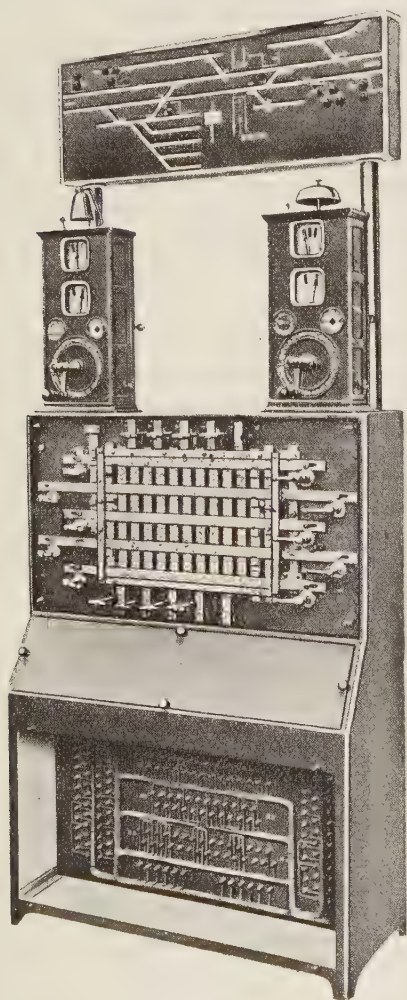


Fig. 19.

point levers are seldom mechanically interlocked, although in certain cases it may be very convenient to use direct lever interlocking. In this connection, we wish to refer to what has been said in the preceding Chapter on this subject.

6. Measures to be taken in cases of failures.

We will now give particulars about the steps taken to meet failures in interlocking plant.

The *Northern Rys. of Spain* state that they do not take any measures for the signal to remain in the stop position. The *Portuguese Rys.* and *Egyptian State Rys.* operate the trains under the control of authorized employees, the points being separated from the operating apparatus.

The *Italian State Rys.* prescribe periodical visits of the interlockings and all the other parts of a control cabin installation, in order to prevent failures, as it is obvious that here again prevention is better than cure.

Failures do not often occur in mechanical interlockings, but if they do occur, they are mostly due to the wear of the

mechanical parts, and these periodical inspections have eliminated this cause of failure in mechanical interlocking.

If, however, there should be a failure, the levers are taken off and an authorized official examines the point-operating levers before ordering the signal to be set at *line clear*. This is in accordance with the precautions prescribed in cases of alterations of the interlockings, brought about by altered working conditions of the box.

If the signal and point operating and control gear work normally, the operation of the signal box may take place under special regulations, as the interlocking must be considered as non-existing.

Failures in electric interlockings are much more frequent than in mechanical interlockings, and are caused by:

- (1) Failures in the electrical insulation;
- (2) Breakage of the conductors;
- (3) Contacts between conductors;
- (4) Residual magnetism from the electromagnets;
- (5) Failures of a mechanical nature in the lever locking devices.

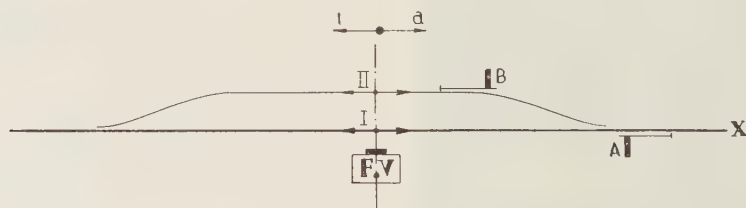


Fig. 20.

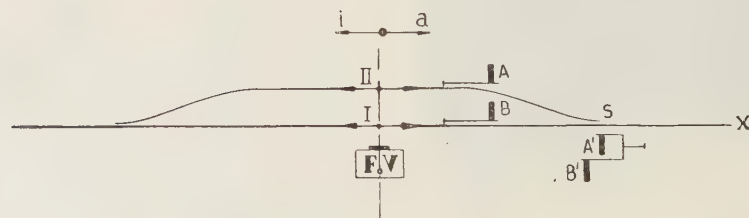


Fig. 21.

If the conductors are carefully installed, the circuits will be well protected against the dangerous causes (1), (2) and (3).

Failures due to saturation can be reduced to a minimum if in the purchasing specifications high grade iron is specified for the electro-magnets.

The *Italian State Rys.* have studied the possibility of avoiding this cause by means of a circuit arrangement feeding the lever locking electro-magnets, in which the flow of the current is reversed at each operation.

Failures grouped under (5) may be reduced to a minimum by using the simplest possible mechanical parts.

These precautions have proved very useful in decreasing the number of possible failures in electrical interlockings, and steps are taken so that if such failures do occur, they are always on the safety side.

Aside from the above precautions affecting the electrical and mechanical interlocking apparatus, the Railways only insist on the checking of the point lever or route lever position before setting the signals at *line clear*; they further insist that before the levers are moved to the position corresponding to the *stop* position of the signal, it must be proved that the train has entirely passed the point on the track where the release of the lever should have taken place.

In 1935, the *Italian State Rys.* enforced the instructions which had been published in 1933, in connection with the operation of electrical interlocking frames of the Westinghouse and A. E. G. systems, installed on their lines (3 720 Westinghouse levers in 51 boxes, and 2 110 A. E. G. levers in 66 boxes); they also enforced the instructions regarding the operation of the electrically-operated boxes of the F. S. type, designed by their Works Department. At present, they have more than 100 of these boxes, with 2 500 levers.

These instructions describe the method to be followed when, due to a failure, electrically-operated points are to be operated by hand; also what is to be done if a track circuit does not work, and if a signal does not go to *line clear*.

Failures are very rare, but they must be prevented by all possible means, as they could seriously interfere with the traffic, especially in the power boxes of large stations.

* * *

CHAPTER III.

Safety devices used in power-operated signal boxes.

7. Foreword.

In this Chapter we shall deal with the principal safety devices used in power boxes, and shall explain what the various Railways have done in this matter.

We shall examine the following devices :

1. *Indication locking of a lever in connection with the actual operation of the signals or points operated by which a lever cannot complete its stroke unless the points or signal have completed their movement.*

2. *Indication locking of a signal lever in connection with the actual position of the points.*

3. *Point locking*, i.e. making sure the points cannot be moved while a train is running over them.

4. *Section locking*, an arrangement which prevents a signal from going to *line clear* unless the track section governed by this signal is unoccupied.

5. *Route locking or traffic locking*, i.e. an arrangement which prevents the setting at *danger* of a signal behind a train which has not run through its entire route in the area governed by the

box from setting up another and conflicting route.

6. *Approach locking*: i.e., an arrangement which, when a route A has been set up, prevents the setting up of another and conflicting route B (after returning to danger signal A), unless the signalman has received positive assurance that the train expected on route A has come against the distant signal in the stop position.

7. *Road occupation security*, i.e. automatic setting to danger of signals.

8. *Conditions governing the release of the levers of a signal.*

9. *Point and signal control indications and approach indications.* — Control of correspondence.

10. Measures to be taken in case of failure.

8. Indication locking of a lever in connection with the operation of points and signals.

(a) *Indication locking in connection with the operation of points.*

Several Railways which have replied to our inquiry have some arrangement in their power boxes by which a point lever cannot complete its stroke unless the point operated in the field has completed its movement. These Railways are the following:

Italian State;
Egyptian State;
Rumanian State;
Northern of Spain;
Bern-Lötschberg-Simplon.

The *Portuguese Rys. Co.* do not have such a control.

In the electrically-operated boxes of the *Egyptian State Rys.* and in the *Italian* installations of the A. E. G. type, this control is obtained by means of electric apparatus which lock the point levers when the points are in the control awaiting position, without the intermediary of relays cutting the points operating current, and even without a

point control relay separate from the lever control.

In the electric power boxes of the *Northern Rys. of Spain*, and *Portuguese Rys. Co.* and the boxes of the Westinghouse type of the *Italian State Rys.*, the point operation control is carried out without cutting the operating current, by using electric locks mounted on the levers, which are energized when the lever is on the point of being controlled (waiting position), the current coming from the point position control relay.

On the *Bern-Lötschberg-Simplon Ry.* this control is carried out by relays directly cutting the operating current for the points to be locked.

In the hydraulic power boxes of the *Italian State Rys.* the control of the points operation is ensured by the well known « Bianchi-Servettaz » device, consisting of a bolt, which locks the lever in the waiting position. This bolt is operated by water under pressure sent to the lever when the point has effectively followed in the track the movement of the lever, after which the latter can complete its stroke.

(b) *Indication locking in connection with the operation of signals.*

The *Northern Rys. of Spain* do not consider such a control necessary for signal levers.

Nor do the *Italian State Rys.* have it in their electric or hydraulic installations, except in the A. E. G. type plant wherein the signal lever cannot complete its stroke unless the signal has followed the movement of the lever.

The reason for this difference between point and signal levers lays in that the signal lever cannot be placed in the line clear operating position unless the point lever, and consequently the points, are in the desired position.

In electrically-operated boxes it is also required that for the signal lever to be set at *line clear* the indication locking of all contiguous tracks must

be obtained. It is also required that conflicting signals are effectively at *stop* and that the track circuits in the route are clear.

In practically all the hydraulically-operated boxes of the *Italian State Rys.* the complete stroke of the signal levers from their normal position to that corresponding to the *line clear* signal can be made without any electrical condition, provided of course that the point levers are in the final position after completion of the stroke corresponding to the position that the points must occupy in the field. However, these last years, after electric boxes were installed, in which inter-dependence of a signal and its control lever was obtained, an apparatus has been designed and built which can be applied to each hydraulic signal lever to obtain the same inter-dependence. This apparatus can be universally used, as it can be applied both to point and signal levers, both in the waiting position and the release locking position.

9. Indication locking of a signal lever in connection with the actual position of the points and signals.

All the Railways which have replied to our questionnaire, effectively use for the signals, such a control arrangement to ensure that all points are properly set and all conflicting signals are at *stop* before a signal can be set at *line clear*.

The methods followed in the various countries differ considerably. For instance, the *Northern Rys. of Spain* operate the signals (colour light) through relays fed through contacts in the point indication relays.

On the *Italian State Rys.* the colour light and semaphore signals are operated in a similar manner in the case of the electrically operated boxes and many of the hydraulic boxes.

In one of the next paragraphs we shall give the diagrams showing the principles on which they are based.

10. Constant signal indication control.

The general rule adopted in Italy for the constant control of signals is to use polarized three-position relays (fig. 22) operated by commutators mounted on the pivot of the semaphore arms.

Figures 22, 23 and 24 show how the commutator reverses the direction of the control indication current when the semaphore arm moves from the *stop* position to the clear position.

In the intermediate position of the arm (fig. 24) the relay is protected by the safety c. c. n.

The operation of the control relay of the colour light signals is shown in figure 25, which gives the signal indication control, and lighting circuits control.

11. Constant detection of the position of the points.

Constant detection of the position of points can be made either directly (A. E. G. system), or through relays, as in the majority of Anglo-American systems.

We have preferred the latter system — in order to standardise the control of points operated from electric and hydraulic boxes — to the control of points operated by mechanical transmission (rodding, wires, etc.).

Thanks to the system in which the points position is controlled through relays, we have also obtained uniformity in the way the corresponding control lever combinators are mounted.

The principle is always to control a polarized relay by two line conductors, in which the feed current flows in one direction or the other, corresponding to the normal or reverse position of the point respectively, and to protect the relays by means of a safety c. c. n., when the points are not home.

Reversal of the control current is made as follows:

(a) By devices included in the point-

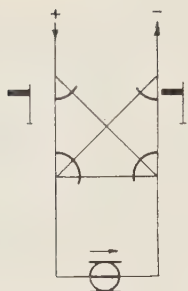


Fig. 22.

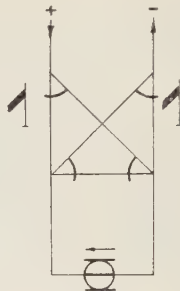


Fig. 23.



Fig. 24.

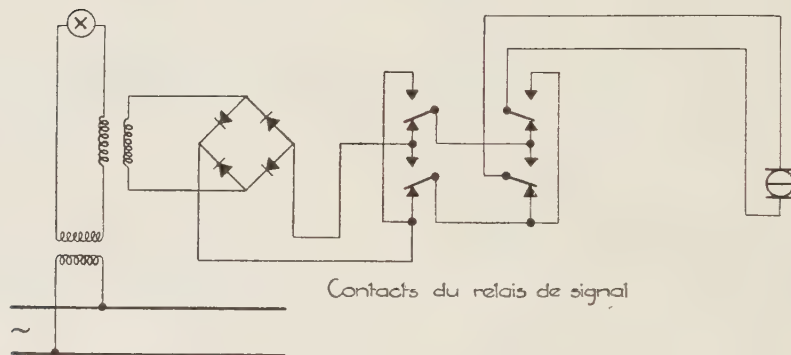


Fig. 25.

operating machine, if the box is electrically-operated.

(b) By special commutators which are applied to the points, if these are controlled from a hydraulic cabin, or if they are manually operated, by wires or rodding.

These controls can be fed, either with D. C. or A. C., or by both.

We mention hereafter two apparatus which may be of interest, viz. :

(a) The polarized D. C. control relay with metal rectifiers;

(b) A system of A. C. point detection without commutators.

*Polarized D. C. control relay
with metal rectifiers.*

The working diagram of this relay is shown in figure 26. This relay is ob-

tained by combining two D. C. neutral relays, R 1 and R 2, with 4 operating rectifiers 1, 2, 3 4 and two safety rectifiers 5 and 6.

The *Italian State Rys.* use these apparatus on a large scale. They are installed with their rectifiers on terminal boards fixed on iron panels, on which the wiring is done without the relays. Through this system of detachable relays, the following two safety features are obtained :

— possibility of making the wiring of the relays independent from the conductors, as they are connected to the terminal boards, which in turn are fastened to the panel;

— possibility of preventing the relay, when connected to the installation, from taking another position than that intended for its normal working.

A. C. point detection without commutators.

This point detection is obtained through electric currents flowing when a magnetic circuit closes, which closing is only possible when, in the two positions of the points, the point blades reach their proper position within the allowed limits and tolerances.

Two small transformers of the adjustable air gap type are fastened to the stock rails.

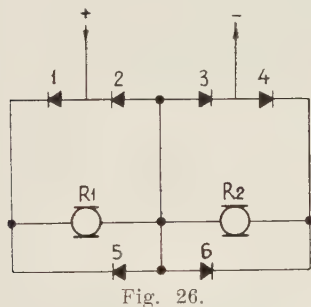


Fig. 26.

The movable part which controls the air gap is fastened to the point blades by means of a small spindle (fig. 27).

The air gap is minimum when the point blade is home — with the allowed tolerance — and is maximum when the blade is in the opposite position.

The primary windings are series connected as are the secondary windings, but in one of the two connections, it is necessary to make a reversal as shown in figure 28.

Assuming now that the position of the points is that shown in figure 27, transformer T_1 will have the maximum air gap, while transformer T_2 will have the minimum air gap.

According to the diagram shown in figure 28, T_1 will operate only as a transformer, while T_2 will, in its secondary winding, only produce a negligible current.

A. C. energy of a given momentary polarity, shown for example by the

arrow *a*, will flow through circuit A, B, C, D, E, F including the two secondaries of the detection transformers and the polarized detection relay, and consequently the relay will be energized, the right for instance.

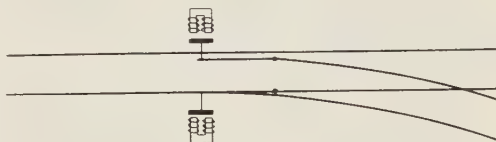


Fig. 27.

When the points are moved to the position opposite to that shown in figure 27, the air gap will be minimum in transformer T_1 and maximum in transformer T_2 , and consequently, the momentary polarity produced in the secondary winding of this transformer — although being in the same direction as that produced in the preceding case in the secondary winding of T_1 — will,

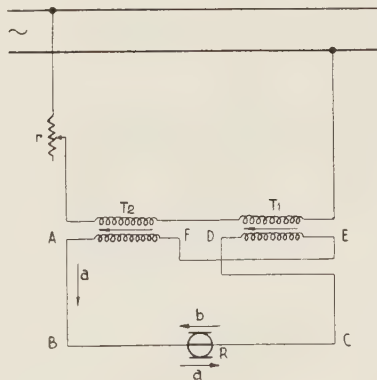


Fig. 28.

owing to the reversal of the connections, cause a current to flow in the reversed direction, i.e. F, E, D, C, B, A, and consequently the relay will be energized to the left.

If the point is in a not well defined position, the two transformers T_1 and T_2 have an open magnetic circuit; the relay then receives practically no cur-

rent, i.e. remains de-energized. Neither will it receive any current if, due to any kind of failure, the magnetic circuits of the two transformers are closed, because in this case there will be two similar voltages but contrary polarity at the terminals of the two secondary windings. This is shown by the polarity and voltage diagrams.

Thus, it is possible with this system to control with only one relay the position of any number of point blades. The connections between the different point transformers for the detection of two and three pairs of point blades, through a single relay, are shown in figures 29 and 30.

It should be pointed out that, whatever the number of pairs of points to be controlled by a single relay, a single reversal of connections is sufficient.

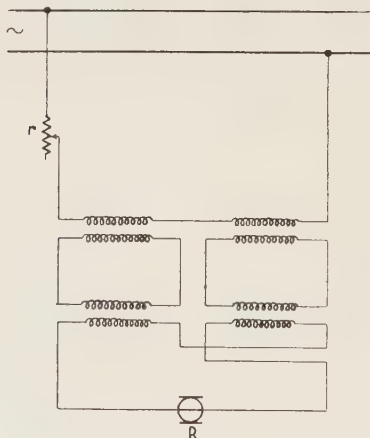


Fig. 29.

Finally, the analysis shows that the consequences of failures (one or two simultaneous failures) are not dangerous.

D. C. constant point detection, either for non-electric boxes, or for manually-operated points (by wires, rodding, etc.).

When D. C. is used for the detection

of points governed by non-electric boxes, or boxes operated by wires or rodding, or points worked in situ, a wiring diagram as shown in figure 31 is used, which, as shown by figure 32, can be used for any number of pairs of points.

This diagram and the detectors employed allow for all the conditions required on the *Italian State Railways*, viz. :

(a) That detection be carried out for both the open and closed switch tongues;

(b) That the tolerance allowed for the closed tongue be 4 mm. ($5/32''$) while the tolerance for the other tongue is consider-

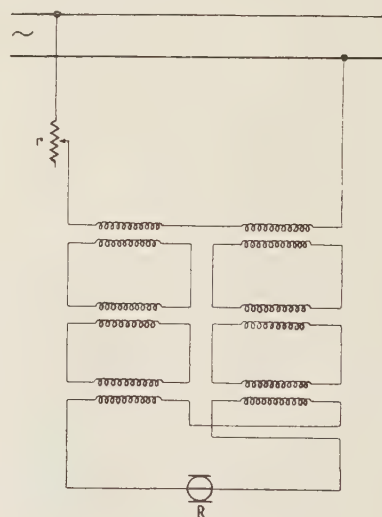


Fig. 30.

ably larger; the detection must not fail even if this tongue is 60 mm. ($2\ 3/8''$) away from the stock rail;

(c) If the detection fails, because the points are not in the desired position and outside the allowed tolerances, the contacts of the point commutators must establish a neutral safety short-circuit protecting the point detection relay.

There are special standards for the assembly and installation of the appa-

ratus, and to ensure the efficient protection by the c. c. n., even in the case of two simultaneous failures.

When a relay controls one pair of points only, the c. c. n. contacts of the point commutators are controlled automatically, because, as shown in figure 31, the contacts of the short-circuit intervenes partly to form the circuit feeding the control relay when the points are in the normal position, and for the other part, in making up the circuit feeding the same relay when the points are in the reverse position.

With the use of constant point detection it is usually possible in the case of hydraulic power boxes to operate with one movement of the lever, and to often obviate or reduce the number of visits to the points in the case of boxes with wire or rod transmission.

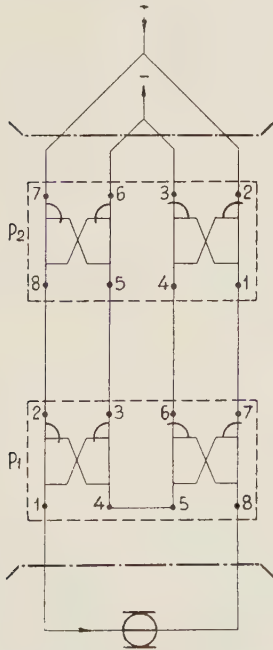


Fig. 31.

12. Section locking.

Having described very briefly the arrangements for the constant detection of points in non-electric cabins, we shall deal with the question of section locking.

In this connection, we wish to repeat that the conditions allowing the clearing of a signal are as follows :

- (a) proper position of the points;
- (b) stop aspect to be shown by conflicting signals;

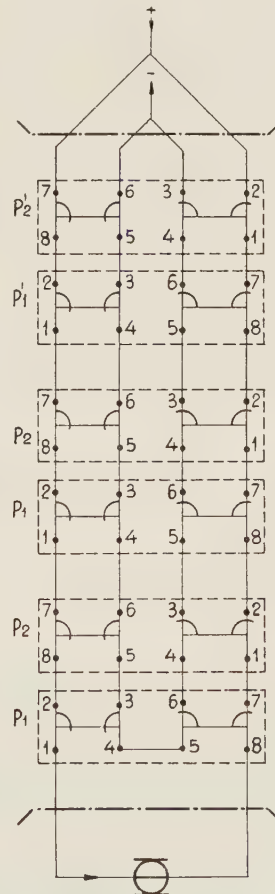


Fig. 32.

(c) inoccupation of track-circuited sections over the route governed by the signal to be set at *line clear*.

The *Italian State Rys.* insist also that, if the signal to be set at *line clear* is one indicating a speed restriction, the lamp of the high signal on the same double bracket be alight. This is a very important safety measure, as the reduced speed indication displayed by the lower signal of a double bracket type signal is valid only if accompanied by a high signal alight or semaphore arm.

Finally, the same Railway System also prescribes that a signal lever cannot be reversed if its releasing device is not in the normal position, i.e. if the releasing device in the field is not in the normal position.

Among the other Railways which have answered to our questionnaire, the following impose the conditions mentioned below for the setting at *line clear* of a signal operated from an electric cabin :

(a) That the track circuits involved be clear (Egyptian State, Portuguese Rys. Co., Rumanian State, and Northern of Spain);

This condition is not required by the Bern-Lötschberg-Simplon Ry.;

(b) That the conflicting signals be at *stop* (all Railways);

(c) That the points be in the proper position (all Railways).

13. Conditions necessary to hold a signal in the « *line clear* » position.

When a signal lever has been duly reversed and the signal concerned is displaying the *line clear* aspect, the question arises whether, to hold the signal in the *line clear* position, it is necessary to maintain all the conditions required for the initial operation of the lever in question.

All Railways consider it necessary to have constant detection of the points

included in the route, in order to hold a signal in the *line clear* position.

In order to determine whether it is desirable that the second condition for clearing a signal (viz. that all conflicting signals be at *stop*) is also necessary for maintaining the signal in that position, it must be remembered, first of all, that the operation of the signals, whether electric or not, concerns two fundamental types :

- slotted signals;
- non-slotted signals.

The former are automatically put to *danger* every time the feed to the slot is cut, even if the operating lever is not returned to the normal position (corresponding to *danger*). The second type of signal displays the *stop* indication only when operated by the lever.

However, there is also a third type of signal, or rather of signal operation : these are the signals which are set at *line clear* by electric current, but which return to *danger* if the current to the slot is cut, and which finally, are operated to *danger* by current sent out when the lever is replaced to normal.

The signals of the third type have still another arrangement by which the signals, which went to the *stop* position due to an interruption of the feed current to the slot, cannot be cleared unless the operating lever is replaced first in the normal position, and then reversed again.

The first and third types of signals give the lever release conditions by which the lever cannot be replaced into the normal position if the signal has not gone to *danger*.

It is obvious, therefore, that for the signals of the first and third types which meet the above condition, and which belong to power boxes having of course interlocking between levers of conflicting signals — whether they are electrical, mechanical, direct or indirect — the second condition is not necessary to put the signal in the *line*

of an occupation indicating arrangement showing whether signals D or C, which control respectively arrivals on tracks III and IV, have been passed by the first pair of wheels.

In this case, to *reverse* the operating lever of signal D (for track III) it is necessary, in addition to the normal detection of points 1 and 2 and points 3, 4, 5 and 6, that track circuits 1, 2, 3 and D shall be clear and that the repeater of signal C (conflicting with D) be at *stop*.

After having reversed the lever of signal D and the latter is in the clear position, the necessary condition required to hold it in this position is that

the detection of points 1, 2, 3, 4, 5 and 6 be maintained, but it is not required that track circuits 1, 2, and 3 remain energized, as they can no longer be occupied by trains, because the detection arrangement of points in the station does not allow it in this case. However, it is necessary that track circuit D shall remain clear, as its function is to produce *permanent* occupation indication of this signal, as soon as the first pair of wheels enter the circuit.

The exclusion from the necessary control conditions — to hold a signal in the *line clear* position — of the track circuits which can only be occupied by a train for which the signal has been

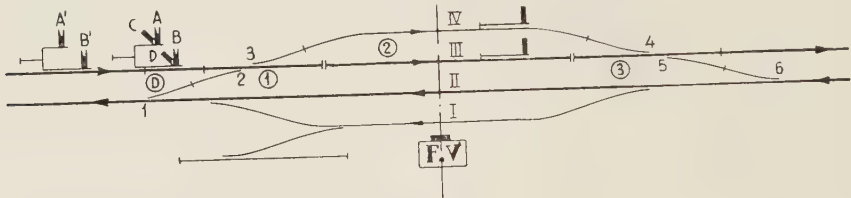


Fig. 34.

set at *line clear* has been carried into effect in order to increase the regularity of the traffic without, however, diminishing the safety factor.

In cases where the track circuits can be occupied by a train, even if the signal is at *line clear*, as in the example shown by figure 34, it is required that the free condition of track circuits 1, 2 and 3 exist in order to enable the lever of signal D to be moved from the normal to the reverse position, as well as to hold the signal itself at *line clear*.

It is obvious that to hold a signal at *line clear*, it is not necessary to exact the fifth condition prescribing that a signal lever cannot be reversed if the lever in the normal position is already free.

In conclusion, of the five conditions required to put a signal in the *line clear*

position, one only is always considered necessary to hold it in that position, and that is the point detection.

In the case of low bracket signals it is equally necessary to consider the lighting up of the lamp in the high signal as a necessary condition.

Of the other three conditions, the one specifying the free condition of the other track circuits must be considered necessary in specific cases only; finally, the other two conditions need never be considered necessary. The conditions with respect to authorities will be dealt with separately.

Therefore, by referring to figures 33 and 34, the conclusion is that the signal goes permanently to *danger* when detection has been omitted on any one of points 1, 2, 3, 4, 5 and 6 and if track circuit D is occupied; but it will have

to be admitted that the returning to danger of the signal is temporary if the non-occupation control by track circuits 1, 2 or 3 is lacking.

The possibility of eliminating from the conditions necessary to hold a signal at *line clear* part of the conditions necessary for reversing the signal lever offers the advantage of giving a greater flexibility to train operation. In fact, in case of a momentary failure of a track circuit, artificial releases of signal levers can be avoided, for repeating the setting to *line clear*. It is obvious, on the contrary, that the occupation of the track circuit D causes the automatic return to danger.

14. Point locking.

Among the most important safety devices, those by which a point cannot be operated while a train is passing over it, must be considered in the first rank.

In non-electric power boxes, and in boxes operated where points are operated by the simple transmission of the operator's muscular effort, in order to prevent the operation of the points when a train is passing over them, the well known mechanical lock bar (treadle) is used.

This lock bar acts in conjunction with the points going from open to closed position or vice-versa, because its function is to detect, before the points are unlocked, whether the points are unoccupied for a distance greater than the maximum wheel base of a vehicle, this distance being measured from the point of the switch tongue. If the condition exists, the points can be unlocked, after which they can be moved and relocked in the new position.

In other words (boxes operated hydraulically, or by wires or rodding), in this case operation takes place in 3 steps, as follows :

- (a) Detection of clear condition of points and unlocking;
- (b) Movement of the point blades;
- (c) Locking.

In electric cabins, the locking of the points is not obtained in a direct manner as described for the above case.

We note from the answers received to our questionnaire that point locking is obtained by means of track circuits which do not directly lock the point, but the point operating lever by the lever lock mounted on the operating lever. This procedure appears to be general in the case of electric power boxes. Also the *Italian State Rys.* have adopted it.

We wish to make the following comments in this connection :

It appears that *direct* locking of the points in non-electric signal boxes, by the lock bar, is more effective than that obtained in electric power boxes with individual operation by means of track circuits acting on the locking devices mounted on the corresponding operating levers.

Although the first system seems more effective, its installation becomes more and more costly due to the present tendency to increase the wheel base of vehicles, hence the necessity for lock bars of increasing length, the installation and maintenance of which are becoming more and more difficult.

At present, the lock bars must have a minimum length of 16 m. (52' 6"), which means that the distance between points of two opposite switch tongues must be up to 16 m., which is not always possible. On the contrary, it is always possible to lock points by means of track circuits, and if the necessary precautions are taken, this system can be used effectively and satisfactorily.

One of the precautions to be taken is that a lever should not be left in mid-stroke, after having passed the locking position controlling the clearing of the track circuits which lock the points. After it has passed the point locking position, and thus controlled the release of the track circuit and after it has remained in this position a sufficient time to allow the locking of the

switch, a point lever might operate the switch when moving to the point locking control position. To prevent this occurrence, the *Italian State Rys.* use an auxiliary electro-magnet the function of which is to complete the operating control circuit only when the lever is in the full normal or full reverse position awaiting detection, and only if at that *precise instant* the locking track circuit is free. They are considering a device by which it is proposed to directly lock the point operating motor when the corresponding locking track circuit is occupied.

15. Occupations and liberations (Locking and releasing).

These two functions used in signalling installations are very important, and are, so to speak, the basis of the signal operating circuit diagrams. We shall therefore dedicate a special paragraph to these functions.

(a) Various kinds of locking and release.

As is known, the signal and authority occupation (locking) — which will be represented by the letter O — as well as signal lever, indicator, route or authority liberation (release) — which will be represented by the letter L — are of various kinds, and they can be divided in several groups according to :

— the means by which they are accomplished;

— the time they last;

— whether they are caused by the first or the last pair of wheels of a train.

As they are generally obtained electrically, we will deal first with :

— the occupation and liberation (locking and release) by the *action of current* (Ac) or by absence of current (Mc) (*manque de courant*).

According to the time the functions

last, we shall call them : Occupation or liberation :

— *Permanent* (marked P) occupation or liberation if, the action once taken, i.e. the signal or authority once occupied, or the lever once released, either by the passage of a train on the corresponding field device or the suppression of one of the conditions necessary to hold it, neither the signal can be restored to line clear nor authority given without some human action consisting, for instance, in the operation of a lever, etc.

— *Temporary* (marked T) locking or release if, once produced, either by the passage of a train over the corresponding field device, or by the suppression of one of the conditions necessary to produce it, this locking or release persists only while the train is passing over this device, or while the above mentioned condition is absent, whilst it is re-established automatically when the condition is again obtained.

— *Mixed* (marked M) when locking or release is permanent (constant) under certain conditions and temporary under other conditions.

In conclusion, there are twelve different types of locking and release the following six being for absence of current (Mc) :

(1) O. P. 1. A. Mc (Permanent locking by the first pair of wheels and by absence of current).

(2) O. P. U. A. Mc (Permanent locking by the last pair of wheels and by absence of current).

(3) O. T. 1. A. Mc (Temporary locking by the first pair of wheels and by absence of current).

(4) O. T. U. A. Mc (Temporary locking by the last pair of wheels and by absence of current).

(5) O. M. 1. A. Mc (Mixed locking by the

first pair of wheels and by absence of current).

(6) O. M. U. A. Mc (Mixed locking by the last pair of wheels and by absence of current).

And the six types of locking by presence of current are :

- | | |
|---------------------|----------------------|
| (7) O. P. 1. A. Ac. | (10) O. T. U. A. Ac. |
| (8) O. P. U. A. Ac. | (11) O. M. 1. A. Ac. |
| (9) O. T. 1. A. Ac. | (12) O. M. U. A. Ac. |

For the liberation (release) we have :

- | | |
|---------------------|----------------------|
| (1) L. P. 1. A. Mc. | (7) L. P. 1. A. Ac. |
| (2) L. P. U. A. Mc. | (8) L. P. U. A. Ac. |
| (3) L. T. 1. A. Mc. | (9) L. T. 1. A. Ac. |
| (4) L. T. U. A. Mc. | (10) L. T. U. A. Ac. |
| (5) L. M. 1. A. Mc. | (11) L. M. 1. A. Ac. |
| (6) L. M. U. A. Mc. | (12) L. M. U. A. Ac. |

(b) *Various kinds of occupation (locking) used.*

This being so, it is needless to state that, for the locking, the principle of absence of current (normally energized), and for the freeing, the principle of action by current (normally de-energized) should always be used. This is done by all the Railways having replied to our questionnaire.

Of the twelve types of locking and release, the six O.Mc. and the six L.Ac. should be employed.

The *Bern-Lötschberg-Simplon* and *Northern Rys. of Spain* always use constant locking.

The *Portuguese Rys.* use temporary locking, either due to lack of point detection or lack of signal control indication. On this Railway locking is constant when there is no authority, as in this case the relay giving the authority is definitely de-energized and cuts the holding and feed current from the signal.

In two of their power boxes, the *Rumanian State Rys.* use constant locking for the entrance unto secondary

tracks, while for the entrance unto and exit from running roads the locking is temporary.

In another box of the *Rumanian State Rys.* the locking is only for the entrance unto all the tracks, and temporary for the exit from these tracks.

On the *Egyptian State Rys.* the electric signal operating mechanisms are either of the type which returns to danger by the lack of current, or do so by the presence of current and therefore, once the locking condition is obtained by the lack of one of the conditions necessary to hold a signal in the clear position, it is always necessary to again move the lever.

According to the definition given before, these lockings are always constant.

All the Railways which have replied to our questionnaire make the locking effective when the first pair of wheels passes over the necessary field device.

The *Italian State Rys.* generally use mixed control by absence of energy, i.e. constant control when certain conditions necessary to hold the line clear indication of a signal are absent, and temporary control when other conditions are lacking.

The return to danger of a signal is usually caused by the passage of the first pair of wheels. However, on lines where locomotives at the rear of the train are used, the signal is restored by the last pair of wheels.

(c) *Some considerations.*

In order to obtain the mixed control of the signals, i.e. to make the locking of a signal permanent or temporary, according to circumstances, without making the signal operating circuits more complicated, electric operation of signals should only be used to set the signal at line clear.

It could be objected here that the operation of a signal from clear to danger merely by gravity may give rise to cer-

tain dangers under unfavourable climatic conditions (snow, ice, etc.) which could prevent the semaphore arm from moving into the stop position.

To prevent such a dangerous possibility, it has been decided that the return to normal position of a signal lever shall be conditioned by the stop indication of the signal having been checked.

(d) *Wiring diagrams for mixed occupation.*

The principles as shown in figures 35 and 36 are used to obtain mixed locking.

A normally de-energized relay H is fed by a circuit which has the conditions Cp in series, and when these are absent, there is permanent locking and, further, there are two contacts, one made by normally energized track-circuit relay E and one in the signal lever when it is in the position corresponding to *stop*.

When all the Cp conditions are obtained (fig. 35), the winding of relay H is energized and sticks by means of one of its contacts.

In the operating circuit of the signal, the following are put in series : the conditions which must temporarily cut off the signal itself when one or more of these conditions are absent ; a contact of relay H when the latter is energized, and a contact of the signal lever when the signal is clear.

It is easy to see that when conditions Cp and Ct are obtained, and when the field locking device (repeated in the box by relay E) is in the normal position, relay H sticks (fig. 36), operates the lever of signal S, thus setting the signal at *line clear*.

However, if one or more of the Cp conditions are absent, relay H (fig. 35) is de-energized and the signal is put to danger, whereas to clear it, it is necessary to put the lever in the normal position first, and then reverse it again, pro-

vided the missing conditions have been re-established.

If it is a Ct condition which is absent (which must govern the signal temporarily) the signal itself returns to danger (fig. 36), but is cleared automatically if the missing condition is again obtained.

Figure 35 applies to the case of occupation by the first pair of wheels ; if this is by the last pair of wheels, the only alteration in the diagram is to replace the contact of relay E by the repeater relay of the field device.

One of the principal Cp conditions — in the absence of which the signal is permanently put to stop — is always point detection. In fact, the regulations do not allow that the signal be set at *line clear* for a route over points the detection of which has failed, even if this detection is subsequently obtained without a well known cause. In this case the point must be examined in the field before changing the position of the signal.

The integrity of the field device is another condition which, if absent, causes the signal to display permanently the danger indication.

On the other hand, may be considered as Ct conditions i.e. conditions causing only a temporary stop indication of the signal, the line clear circuit conditions. The authority to proceed should be con-

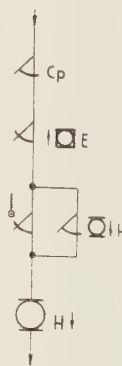


Fig. 35.



Fig. - 36.

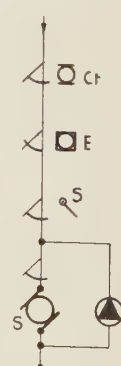


Fig. 37.

sidered as a Cp condition. These diagrams of mixed occupation can easily be used either to obtain permanent or temporary occupations.

Indeed, to obtain the former (O. P. Mc), the contacts set up for the Ct conditions will be left out from the diagram, figure 36. To obtain the second (O. T. Mc) figure 35 must be disregarded, and in figure 36 the contacts established by relay H will be replaced by the contact of relay E (fig. 37).

Needless to state that to obtain the temporary and permanent occupations with the last pair of wheels, it will be sufficient to substitute in the above schemes for the repeater relay E, the repeater relay of the field occupation device operated by the last pair of wheels.

(e) Field occupation arrangement.

From the answers received to our questionnaire, we see that track circuits are generally used to obtain the occupation. This arrangement normally consists of :

— a normally energized track circuit by means of direct or alternating current, for occupation by the first pair of wheels ;

— for occupation by the last pair of wheels, the *Italian State Rys.* use two track circuits, through the first of which current permanently flows, and the second is normally without current.

If Rp and E are the two relays of the track circuits in question, the principle of occupation by the last pair of wheels is given in the diagram, figure 40, where 0 is the repeater relay of the field device. Indeed, when the two track circuits are free, relay 0 is fed by the contact on relay E; when the train passes the first track circuit, the polarised relay Rp is energized in the other direction, and makes its contact, and consequently relay O is fed both by the contact of relay E and by the contact of relay Rp. When the train comes to the se-

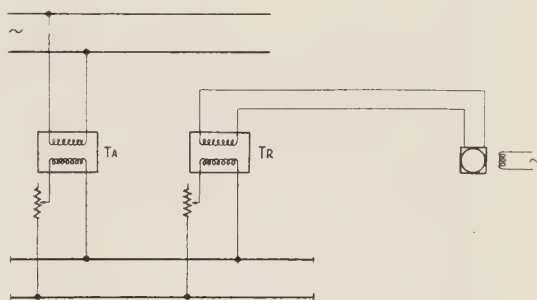


Fig. 38.

cond track circuit, the contacts of relay E drop, but relay 0 is fed only by the contact of Rp. Finally, when the train leaves the insulated joints between the two track circuits, the feed of 0 is interrupted and its contact, which should be substituted for the contact of relay E in figures 35 and 37, causes the signal to go to danger.

(f) Various kinds of liberation (release) employed.

The release comprises those operations by which a signal or route release lever in a position directly or indirectly governing the operation of trains and locked in this position (called reverse) can be automatically disengaged and put in a position to be replaced to normal.

The release should always take place by the action of current sent to the de-

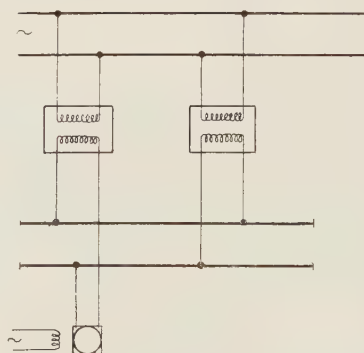


Fig. 39.

vice in the box by another device on the track, operated by the train when the latter passes over the point concerned.

The *Egyptian State* and *Northern of Spain* use release by the last pair of wheels, while the *Bern-Lötschberg-Simplon* obtains the release by the first pair of wheels.

The release must always be permanent, i.e. the lever, push button, hand-lever etc., once released, or free, must remain free until replaced to the normal position.

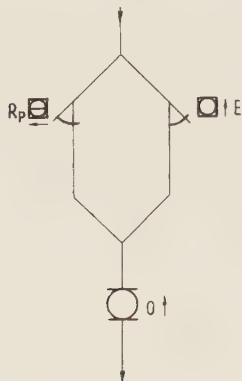


Fig. 40.

The *Italian State Rys.* specify that the release should take place by the action of electric current, actuated by the last pair of wheels, and that this release should be permanent.

(g) *Field device for releasing.*

The field device for releasing by the last pair of wheels consists of a treadle lock bar and a small track circuit the relay of which is normally energized.

The treadle in its normal, i.e. rest position, protects as a c.c.n., through contacts, a relay P located in the signal box and which repeats the position of the treadle (fig. 41).

Another relay Pa (fig. 42) is fed as a stick relay when the signal lever is reversed and the treadle is operated.

The wiring diagram, figure 43, shows the principle of the release; at C are shown the contacts which are established when the necessary conditions for the obtention of the release are present, and in series with the contacts are the contacts of relay E of the track circuit of the release field device and of relay Pa.

When the signal is at *line clear* and its lever reversed and locked in this position, the train, after putting the signal at stop by passing over the field device of occupation, passes over track circuit



Fig. 41.

Note: Contacts de la pédale = treadle contacts.

E forming part of the field release device, cuts the feed of L (release coil of lever) at E, then, passing onto the treadle, energizes P (fig. 41) and, consequently, Pa (fig. 42) thus making the normally interrupted contact of Pa (fig. 43.)

When the train leaves the track circuits, the contact of E (fig. 43) is made again and, if the other conditions neces-

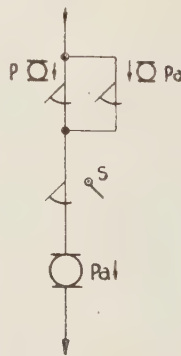


Fig. 42.

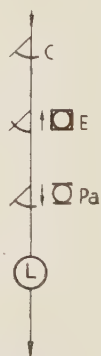


Fig. 43.

sary to obtain a release are present, coil L remains energized, and the lever is released.

By putting the lever of signal S in its normal position (fig. 42), relay Pa will be de-energized, providing treadle P has returned to its rest position, de-energizing relay P.

To control this de-energization, there will be added to the conditions necessary to reverse a signal lever, that relay P should be de-energized; similarly, to control the stop indication of the signal, it is required that in addition to the conditions C (fig. 43) necessary for the release, the signal repeater be at stop.

(h) *Using one part of the locking device for releasing.*

As the occupation arrangements — whether occupation is obtained by the first pair or by last pair of wheels — require always a track circuit normally energized with a relay E and as, similarly, the release device actuated by the last pair of wheels requires a similar track circuit, the *Italian State Rys.* use the same track circuit for putting the signals at stop and for releasing the corresponding levers.

Furthermore, the same devices are used on single track lines for the locking and releasing of home and starting signals.

Obviously, things are always arranged in such a manner that the placing to danger takes place by the absence of current and the clearing by the action of current.

16. Sectional release route locking.

To increase the capacity of large stations, and increase flexibility of operation therein, without endangering safety, it is often necessary to use devices allowing the release of points in a route which has not been completely traversed by a train, in a measure as the points in question are being released.

The *Egyptian State* and *Bern-Lötsch-*

berg-Simplon Rys. do not have sectional release route locking, whereas the *Portuguese Rys. Co., Northern of Spain* and *Rumanian State* do use it; sectional release route locking is equally used by the *Italian State Rys.*

The *Portuguese Rys. Co.* and *Northern of Spain* make these arrangements absolute by the use of track circuits.

In a very important station on the *Rumanian State Rys.*, route locking is used, an arrangement by which the lever of a signal put at stop by the passing of a train can be immediately replaced to danger, while the levers of the points involved in the route cannot be changed unless freed by the passage of the train.

The levers thus released can be used for setting up another route, but only after any conflicting points have been freed.

In the two other power interlockings of the same Railway, the positive route locking has been obtained by the use of insulated areas, another route only being prepared after the first route is quite clear. The route locking is completed by approach locking which may be cancelled by a time release. The approach arrangements of the *Italian State Rys.* operate in a manner similar to that first described.

We are giving below some information concerning the arrangements of this kind used in the Rome terminal and the Florence S. M. N. stations.

The routes between the running road and the sidings have been divided into two parts: one group includes the points between one of the shunting tracks and an intermediate point, and the other includes the points between this intermediate point and the running road.

The operating levers of the points in these two parts are locked in their correct position by means of indicating levers called « shunting lever » and « direction lever », respectively.

For the arrival of a train, after setting the points of the section corresponding

to the direction lever, the corresponding indicator is reversed and remains locked in this position.

From this moment, if the conditions necessary to put and hold a protection signal in the clear position are present, the signal displays the line clear indication.

It is assumed that, to reverse a shunting lever, the following conditions must be present :

1. Points in the proper position;
2. Reversal of partial route levers which govern also the corresponding low signals;
3. Authority received;
4. Free track circuits;

and that to reverse a direction indicator lever, the following conditions must exist :

1. Points in the proper position;
2. Reversal of partial route levers governing also the corresponding low signals;
3. Authority received;
4. Free track circuits;
5. De-energized release relays;
6. Shunting indicator lever reversed.

The conditions necessary to hold the protection signals at line clear, are :

1. Existence of detection of the points involved ;
2. Existence of authorities ;
3. Clearing of the track circuits which may be occupied by a train while the signals are at *line clear*.

If one of conditions 1 or 2 is lacking, the signals are permanently put at stop, while the lack of condition 3 causes the signal to display the danger aspect temporarily only, except if it is a matter of track circuits making part of the signal locking field devices, which would put the signal at stop permanently.

Let us see now how and when the signal is put at stop and the direction and shunting indicator levers are released.

The protecting signal automatically displays a danger indication when the first pair of wheels of the train pass the

locking circuit of the first pair of points of the route.

Of course, the direction indicator lever for arriving trains in its reverse position and in spite of its being locked in that position, can be brought to an intermediate position by which the signal is put to *stop*, without releasing the other partial route levers and, therefore, without releasing the points of the route.

The release of the direction indicator lever takes place after the treadle at the end of the route has been operated by the train, and when the last pair of wheels has left the locking track circuit of the points on the concerned part of the route.

The locking arrangement of the shunting indicator lever releases the lever when the last pair of wheels of the train leaves the track circuit preceding in the field the last point of that part of the route belonging to the shunting area.

The point operating levers which are still being affected by the train remain locked as long as the train itself has not released them.

The interlockings of the installation are also such that once the direction indicator lever is released, the same lever or another conflicting direction indicator lever cannot again be reversed until the shunting indicator lever is replaced in the normal position.

For departures, the operations take place in a similar manner.

17. Approach locking.

By approach locking is meant that, after a route A has been set up, the setting up of another conflicting route B after the signals of A have been put to stop will be prevented, except in the case where the signalman has positive assurance that the train expected on route A will have sighted the distant signal in the stop position. This arrangement may be positive by means of track circuits or insulated sections, or by means of time releases.

In their electric power boxes, the *Egyptian State* and the *Rumanian State Rys.* use approach locking with track circuits, while the *Northern Rys. of Spain* use a time release.

The *Italian State Rys.* have some approach locking devices, but as a rule they use the absolute locking of the signal lever which governs the train movements on one route, it being made impossible to replace the lever in the normal position as long as the last pair of wheels of the train has not left the route itself, entirely or partially, according to the methods and conditions described in other chapters of this report.

We wish to add, however, that in certain electric power boxes the authorities once given may be cancelled up to the moment where the signalman puts the corresponding signal in the line clear position; after this moment, the authority button remains locked.

The *Italian State Rys.* are also considering the installation of an approach locking arrangement by means of track circuits, to be placed in advance of the distant signal, which would allow the signal to display the stop aspect (after having been at line clear), either by cancelling the authority given on the signal itself, or by replacing the signal operating lever in the normal position.

Contrariwise, when a train sights the distant signal and enters the approach track circuit, either the authority button or the signal operating lever would be locked.

In other words, with this arrangement it is possible to delay the locking of the authority buttons and signal operating levers up to the time when the train sights the signal itself.

It is hoped that this arrangement will permit a greater flexibility in the use of the power boxes.

* * *

CHAPTER IV.

18. Indicating devices available to the signalmen.

The following are the principal indicating (repeater) devices located in the signal boxes:

- (a) Signal position repeaters;
- (b) Point position repeaters;
- (c) Track-circuit condition repeaters;
- (d) Control of correspondence;
- (e) Control of signal lighting;
- (f) Other repeaters.

a) *Signal position repeaters.*

All the Railways which have replied to our questionnaire have installed repeaters, for those signals which cannot be seen from the signal box. This repetition is usually obtained in a positive manner for both the clear and danger indications.

In the electric power boxes, the repetition of the signal indication is obtained:

— by means of lamps located on the interlocking machine, on the *Egyptian State Rys.*, and on the *Italian State Rys.* in their first installations;

— by means of lamps mounted on an illuminated diagram, on the *Portuguese Rys.*, *Northern Rys. of Spain*, and in a large number of installations of the *Italian State Rys.*;

— finally, by means of an optical control device, on the *Bern-Lötschberg-Simplon Ry.*

In our opinion, the repetition of the signals should always be positive for all indications.

All of the above Railways consider it essential to repeat in the signal box the indications of those signals which are not perfectly visible from the box.

(b) *Point position repeaters.*

The electric signal boxes on the above mentioned Railways are also provided

with point position repeaters for the points operated from these boxes. This repetition is positive and indicates the normal as well as the reverse position of the points. It is obtained :

— by means of lamps mounted on the interlocking machine on the *Egyptian State Rys.* and on the *Northern Rys. of Spain* ;

— by means of banners and discs mounted in front of the operating levers on the *Portuguese Rys.* and the *A.E.G.* type installations on the *Italian State Rys.*

The *Italian State Rys.* do not have permanent repetition on a portion of their hydraulic signalling installations, but, as stated in an earlier paragraph of this report, they are considering the installation in the immediate future of permanent control of the position of all points operated by hydraulic power.

Repetition of the position of the points should always be positive, for both the normal and reverse position of the points concerned with the actual traffic. All the Railways consulted consider that repetition of the position of the points is necessary.

(c) *Track-circuit condition repeaters.*

Such a repetition is considered necessary by all Railways which have replied to our questionnaire. They also agree in that the repetition should generally be obtained by means of lamps which are alight when the track circuits are free, and extinguished when the track circuits are occupied. These lamps are usually mounted on illuminated diagrams. In the majority of installations, therefore, the repetition is visual, and positive only when the track circuits are clear, although some Railways use an audible repetition by means of a bell which rings when the track circuit is occupied (*Northern Rys. of Spain*).

In some cases, the *Italian State Railways* use the positive track circuit repetition for both clear track circuits (co-

loured white) and occupied track circuits (coloured red).

The *Egyptian State Rys.* use the red light when the track circuits are occupied, and no light when they are free.

(d) *Control of correspondence.*

We have seen in (a) and (b) that the Railways use signal indication repeaters and point position repeaters in the majority of their power boxes. The question arises whether it is advisable to have a device or arrangement to assist the operator in checking the proper position of the signals and points, i.e. to prove that the position corresponds with that of the operating lever. Such a device should give an audible signal to be effective.

The *Portuguese, Northern of Spain and Italian State Rys.* use a bell which is energized when the position of the points does not correspond exactly with that of the lever.

The *Rumanian State Rys.* have a system of indirect control of correspondence, and the *Egyptian State Rys.* use a lamp, which is extinguished when there is discordance.

The *Italian State Rys.* have installed the control of correspondence in all of their electrically-operated boxes, and they are installing control of correspondence between point levers and signal levers in their hydraulic boxes in a measure as constant point detection is being introduced.

With respect to the signals, a distinction must be made between signals governing train movements and signals governing shunting movements.

Eliminating first the necessity of having an indication of this last type of signals, it must be noted that the *Italian State Rys.* do not always have the control of correspondence of the running signals, but in addition to the visual indication of the position of the signals, which as stated before is always positive for the

clear and danger aspects, they use a Leopolder type bell, ringing each time a signal is at line clear or displays any aspect which is not definitely a danger indication.

(e) *Control of signal lighting.*

The *Italian State Rys.* have provided the permanent indication of electrically-lighted semaphore or colour light signals. If lighted by kerosene, the photoscope is employed.

The lighting of signals installed in tunnels is always indicated whatever the system of lighting. When burning paraffine, a photoscope is used.

(f) *Other repeaters.*

The signalling technique, which in these last years has made enormous progress, cannot stop and rest on the results obtained until the present day. It is necessary, to continue the research for better systems, apparatus, etc. providing a higher degree of safety and still more regular running of trains.

While waiting for new designs of apparatus which may be profitably substituted for those which, today, are least satisfactory for their purpose, the operation of the latter must be very carefully watched,

This is why, in addition to the above described indications given in power boxes, it would be very advisable, if not necessary, to indicate as well as control the operation of those apparatus which have not yet attained the desired degree of perfection and which have not yet been replaced by better designs. One of these apparatus is the electric or hydraulic treadle, still little used. The repetition of the operation of the treadle, for instance, is not necessary from a safety standpoint, but only from the point of view of regular running of trains.

We have mentioned before that on the *Italian State Rys* the release of the signal

levers or indicators takes place after the last pair of wheels has passed the signals, and that the field device used in this method of releasing consists of a track circuit and a treadle. We have said, further, that the signal lever cannot be moved out of its normal position *at stop* to the reverse position (*line clear*) if the lever is already released.

By repeating the movement of the treadle in the signal box, it will be possible to quickly ascertain the causes of any failure and to see at once if the failure is due to the treadle, in which case the delay will be reduced to the minimum time required for the repair of same.

(g) *Conclusions.*

For the safety and regularity of train operation, it is necessary to repeat in the power boxes the indications as regards the position of points and signals, together with electro-audible control of correspondance of free or occupied track circuits and the lighting of signals. Further, to increase the regularity of train operation and to reduce the duration of the failures to a minimum, it is desirable to give the operator some indication as to the working of those apparatus which are not perfect and which could not yet be replaced by better designs.

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CHAPTER V.

Measures to be taken in case of failure in power-operated signal boxes.

19. Communication between the station staff and the maintainers of power signalling installations.

The first power boxes have not always been of the electric type in all countries.

In fact, on the *Italian State Rys.* the first installations of this kind were hydraulic, and in 1936, the Administra-

tion celebrated the 50th anniversary of these installations, the first of which was put in service in Abbiategrasso station by Sr. Riccardo Bianchi, the inventor of the system and first General Manager of the *Italian State Rys.*

Also the *Madrid-Saragossa-Alicante Rys.* used to have hydraulic boxes, which, however, were gradually replaced by electric installations.

The measures to be taken in cases of failure were little regulated, but were progressively improved as the number of installed boxes increased.

The *Italian State Rys.* have now three instructions as to measures to be taken in cases of failure :

1. For A.E.G. type electric power signalling plant;
2. For Westinghouse type electric power plant;
3. For hydraulic installations,

and they have recently prepared similar instructions covering their F.S. type power boxes.

In addition, they have issued standard rules defining the relations between the station staff (station masters, signalmen) and the signalling plant maintainers when the latter are called to inspect the apparatus or to make good failures.

These regulations also give the signalmen the sequence in which the various levers must be operated for signals and points concerned in routes for incoming and outgoing trains and non-stop trains. They also indicate the method of operation for the signal and point levers, for the signal levers, whether they have the releasing device with automatic locking or not.

In order to regulate the relations between the station staff and the maintainers, and having divided the functions of the latter into two large groups viz. (a) Those which will not affect the safety of operations, and (b) Those which may affect such safety, it has been laid

down that the maintainers, before commencing the work, have to inform the station staff by means of special printed forms, of the kind of work to be done.

For work of the first group, forms crossed with green stripes are used, and for the other group, forms with red stripes. On receipt of a form of the latter type, the operator must not let any trains pass over the points in the repair area, and therefore, such work must be carried out in the intervals between train movements over the points concerned.

However, the case may arise when it is necessary for a train to run over these points. Then, the station master is allowed to fill in a form crossed in yellow, with which he asks permission to use one or more switches in *given positions*, as promptly as possible.

The maintainers have to grant the signed authorization indicating the various precautions to be taken (locking of points by means of a claw, etc.).

These written communications may also be transmitted by means of a phonogram.

In order to reduce the operating delays to a minimum, the signalmen can, in case of failure and while waiting for the maintainers, make a certain number of movements, which are given for each installation in the special instructions (a) and (b) given above.

20. Conclusions.

We shall briefly sum up the principles applied, as it is impossible for us to go into the details and examine each case.

Generally, a *stop* signal may not be set at line clear if the point detection is lacking. In this case, the train must be made to proceed, with the signal at stop, and the train must be accompanied by one of the station employees, provided with an authority from the station master, after the switch has been inspected and put in condition for the train to run over it.

Contrariwise, it is possible to move

the signal to *line clear* in the case of a track-circuit failure, after shunting the condition either on the feed circuit of the locking electro-magnet of the signal operating lever itself, or on the operating circuit of the signal; before using the push-button allowing the shunt in question, the track circuits must be inspected, and the push-button can only be used if the track is actually free and in order.

The push-button can be used for one train only, i.e. after the return of the signal to *stop*, the lever and the signal itself cannot be put in the *line clear* position unless the push-button is in the normal position, so that it becomes compulsory to again operate the button if, during the track-circuit failure, the signal must again be set at *line clear*.

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CHAPTER VI.

Locomotive cab signals.

None of the Railways concerned have furnished any data with regard to this question, and we shall therefore only give some information in respect of installations of this kind on the *Italian State Rys*.

For several years, this Administration has been considering the installation of cab signals, and has now deemed it a necessity on account of the increased speeds.

In fact, several years ago devices were installed on a 216-km. (134 miles) double-track section for repeating signals in the locomotive cabs, and 33 locomotives were equipped with the necessary apparatus.

The system used was designed by Sr. G. MINUCCIANI, Engineer.

The system was described in an article published in the December 1935 number of the *Bulletin of the Railway Congress*, and we wish to mention only that the apparatus were of the intermittent electro-magnetic type, without mechanical contacts.

Repetition is visual and audible, and applies only to distant signals in the *line clear* and *stop* positions.

The system includes a valve and recorder by means of which the vigilance of the driver is checked, as laid down by the regulations; the latter also prescribe that in case of discordance between the indication given on the locomotive and the aspect of the signal itself the engine driver must obey the indication of the track signal.

During the experimental stage no failures were experienced which were not on the safety side.

Wrong indications on the locomotive, showing the signal at stop while it is actually clear, are approximately 1.5 %.

In view of the satisfactory results obtained as regards safety, this system will soon be extended to high-speed lines of the Italian State Railways.

SUPPLEMENT.

Information supplied by the Swiss Federal Railways.

PART I. — Automatic block signalling.

The *Swiss Federal Railways* have not installed any automatic block signalling apparatus.

PART II. — Remote control of points and signals.

I. — Power operated signal boxes.

These Railways have 695 signal boxes, 54 of which are power-operated, all electrically, covering a total length of 2 876 km. (1 797 miles) of track.

All the power-operated boxes have *individual levers*. No devices are provided for reducing the number of levers.

Most of the interlocking tables are fitted with handles which can be rotated in both directions. Some of the tables are fitted with levers. The Swiss Federal Rys. consider one system as good as the other.

Interlocking.

The interlocking between the two handles controlling conflicting routes or signals is both mechanical and electrical. The electric interlocking is by means of electrically-driven cams acting on the commutators.

In the event of *failure*, the trains are sent forward with the signals at danger, and if necessary without interlocking the points affected. In such cases the man in charge has to take care that the points are in their correct position, and that the line is clear to the next station.

Safety devices.

The signal controlling a given route cannot be put at *line clear* unless all the points to be run over and all the safety catches are in the correct position and up against the stock rail; in addition shunting signals and signals protecting certain points must be at *danger*.

The control is permanent as long as the route signal is at *line clear*. As soon as a point, or a shunting or protecting signal leaves its correct position, the route signal automatically goes to *danger*.

Certain installations are fitted with electric devices (insulated rails, electric treadles), or mechanical pedals (locking bars) which prevent the switch being moved so long as the vehicle is standing on the points.

In some cases electric devices such as track occupation indicators are used which prevent the route signal being put at *line clear* as long as the section of line concerned is in fact not clear.

When a signal at *line clear* is put to danger by the train passing it, the inter-

locking box cannot set up a new conflicting route before the train has completed the route set up or has stopped at the arrival platform.

The release of the route takes place according to the local conditions, either by means of track circuits, or by wheel counters, or by time relays in conjunction with pedal or finger contacts, i.e. contact-making devices actuated by the wheel flange.

The release of the route takes place according to local conditions, either in turn as the different signal boxes are passed, or for the whole route when the train has arrived at the platform or has left the station. At the interlocking box the route set up is cleared either by the train itself or by operating the necessary levers at the control box (the box authorising the route) by the man in charge.

Alterations, in the signal box in a route once set up, is only possible with the consent of the man in the central box who has to carry out certain operations or give certain orders to release the route set up.

There are no devices preventing a route being cleared when the train expected has already passed the signal at *line clear*.

Method of carrying out these arrangements.

This inter-dependence is obtained either by auxiliary apparatus or by relays which cut the authorising current or the coupling current of the signal.

The signals are *automatically set to danger* by a failure of the coupling current.

A main signal put at danger automatically by breaking its coupling current cannot again be taken off until the whole route prepared has been cleared and a new route has been set up.

According to local conditions, the signals at *line clear* are restored to *danger* by either the first or the last pair of wheels of the train.

The signal is restored to danger either by mercury contacts or pedals, or by the track circuits.

The signal put at *danger* by a passing train is prevented from being taken *off* on the site by a mechanical lock in conjunction with the coupling.

The position of the signal is checked in the route releasing circuit, so that it is possible to intervene when a signal has not been restored to *danger* by its motor.

The railway only possesses electrically-operated signal locking equipment.

The railway is of the opinion that thanks to the electrically-operated equipment, the radius of action of the interlocking boxes can be extended, whilst decreasing the number of men required to work these boxes. The setting up of the routes and the operation of the points takes place more quickly than when mechanical equipment is used. In large stations electric interlocking is cheaper than mechanical.

A route can only be released when the signal of the completed route has been put to danger by its motor.

Once the route commutator has been operated it can only be restored to its normal position when the last pair of wheels of the train has passed the point in the track where the releasing device is installed.

The route is cleared by means of pedal or finger contact or by means of track circuiting.

Control devices at the signal box.

The signalmen are responsible for checking the *on* or *off* position of the home signals and the starting signals by watching the optical repeaters.

In addition, the signalmen are obliged to satisfy themselves that the blades have completed their stroke, by watching the control relays and the ammeter of the operating current.

Any authorisation or cancellation of a route or the doubtful position of a switch or a signal is advised, either by a bell

or by an indicator, the colour or position of which is changed.

The occupation of a line is shown by the change in colour of an indicator or by lighting up a small coloured light.

* * *

The Swiss Federal Rys. consider the above-mentioned devices as well as those mentioned under the heading *safety devices* as required in all electrically-operated boxes. In the case of installations in which the leaving routes are regulated by the track signals and the line signals, they do not fit an electric repeating lock at the first of these signals. A track signal which has gone to danger can be taken off without having to clear the route beforehand.

Measures taken in case of failure.

In case of *failure of the electric locking*, it is not always necessary to call on the maintenance staff. The points and signals operating gear can be operated on the site by means of a lever; the operating and control currents must be broken beforehand by removing the corresponding fuses. Lead sealed safety buttons or levers make it possible in case of damage to release routes set up, or to cancel trains accepted, or lines occupied. The pointsmen, however, cannot utilise these safety devices except on the authority of the man in charge of the central power box. This employee has to give his authority in each individual case. Any seal broken has to be entered in the failures book with indication of the number of the train, the date and a short signed justification.

When the defects affect an incoming route, the train is stopped before the signal or point of entry. A home signal which cannot be taken off cannot be passed without a verbal warning to the driver.

Wiring diagrams of the points circuits are made in such a way that a *single* failure in the operating or control circuit

(broken wire, 2 wires in contact, stray current, earth) is revealed by the control relays or the earth control after two separate operations of the point commutator. A dangerous position can arise only in the case of two simultaneous failures.

The diagrams of the electric control circuits are such that a stray current, or an accidental contact between two wires can only act in the direction of safety (a signal which ought to be taken off remains at danger or a signal which should show a single raised arm shows several). Any relay inserted in the electric control circuit has its function controlled at the moment of setting up or clearing the route concerned.

II. — Long-distance operation of points and signals.

No such equipment is used on this railway.

III. — Automatic operation of points and signals.

No points or signals are operated automatically.

PART III. — Locomotive cab signals.

I. — Continuous locomotive cab signalling.

The lines and power vehicles are not fitted with equipment giving a continuous indication of the state of the track run over.

II. — Intermittent locomotive cab signalling.

The railway is installing and extending the « Signum » automatic train control system incorporating permanent way electro-magnets. At the end of 1936 this equipment was fitted on 2 898 track-kilometres (1 800 track-miles), 748 km. (465 miles) of which was single track, and on 374 power vehicles. At the end of 1937 all the electric motor vehicles and diesels were fitted with it, but none of the steam locomotives.

Transmission is by induction.

Signal repetition. — For the time being the danger position of the distant and block signals is controlled. If the need should be felt, it will also be possible to equip the home, the starter and advanced starter signals, as well as temporary speed restriction signals, by conjugating them with the permanent way electro-magnets. In addition, the arrangement lends itself to repeating several indications such as : *stop, through line clear, branch line clear.*

At the moment the train passes the track apparatus (electro-magnets) in connection with the distant signal at danger, the brakes on the motor vehicle are applied automatically. This equipment releases at the same time the « dead man's handle » and the following sequence of events takes place. First of all an alarm signal is sounded in the driver's cab, then after running about 50 m. (164'), the motor current is cut off, and automatic braking takes place. At the moment the equipment comes into action on the locomotive, a control lamp goes out. This lamp usually indicates that the safety equipment of the locomotive is in working order. The action of this device is recorded on the paper band of the speed recorder.

The driver is kept on the alert in the following way. The moment the train passes a distant signal at *danger*, the driver should press on the vigilance button, which prevents the engine apparatus from reacting, no record being made on the speed recorder band. If the vigilance button is not pressed down in time, the above phenomena take place (audible signal sounded lamp switched out, motor current cut off, brake applied) until the button is pressed. The record on the paper then shows the driver's lack of attention.

If the apparatus on the locomotive should fail to act, a second man is used on a single-man operated engine. The speed is not reduced.

The Swiss Federal Rys. are not at pre-

sent in a position to give statistical data of any failures occurring in service.

The tests have given excellent results and since the apparatus has been put into use, only a few cases of it acting irregularly have been found, due generally to slight defects in the equipment or defects in the relays.

The defects, however, all occurred on the safety side, no failure on the danger side having been recorded so far.

Up to the present no defect attributable to the principle of the equipment has been noticed.

Any defects during running must be reported by the driver.

As regards the *advantages* of the system adopted, the Swiss Federal Rys. have expressed the following opinion : The automatic train control system we have adopted protects us against any failure to observe the signals under unfavourable atmospheric conditions or any lack of attention of the driver. We attach great importance to this increased safety, particularly when the motor vehicles are driven by a single man. In addition we expect the drivers to be much more attentive, owing to the fact that

their vigilance is checked. Cases of failure to observe signals are very rare on our railway, and accidents due to this are rarer still. Such accidents, however, can be very serious, and for this reason we think it very important they should be eliminated automatically. This feeling of very great safety encourages the public to travel by railway.

III. — Automatic braking.

In all 2 898 track-km. (1 800 track-miles) are equipped, 748 km. (465 miles) of which are operated as single line.

The braking is independent of the speed of the train.

It takes place some 50 m. (164') after passing the distant signal at danger, shortly after the optical and audible signals mentioned above come into operation. The braking is continued *till the train is brought to a standstill*.

The driver can cut out the automatic brake action by using the vigilance button, either before or after the apparatus acts.

The action of the safety device which applies the brake, is recorded on the speed recorder diagram.

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

13th SESSION (PARIS, 1937).

QUESTION IV.

**Evolution of the rail motor car
as regards its construction, and special investigation
into the transmission and brake questions.**

Comparative methods of testing railcars.

**Detailed investigation into the costs of railcars
and the methods of reducing them.**

REPORT

(North and South America, China and Japan)

by Mr. WANAMAKER,

Electrical Engineer, Chicago, Rock Island and Pacific Railway.

I. — ANSWERS TO THE QUESTIONNAIRE.

A Questionnaire was sent to some thirty Railroads, of which five advised they had nothing of interest to report, and five reported as follows :

QUESTION. 1. — *What was your primary reason for experimenting in the field of design, construction and operation of automotive or rail motor equipment?*

A) Reading Company. — Reduction of traffic and lower operating costs made it necessary to look to other fields to provide cheaper power, to maintain service. Investigations were made as to the adaptability of motor cars, resulting in placing in pas-

senger service for a period of time, 13 gas-electric motor cars, 2 oil-electric motor cars and 2 oil-electric cars for switching service.

These cars operate trains which consist of motor car, trailer, standard passenger, standard mail, and freight cars.

B) Entre Rios and North-East Argentine. — (a) Before road competition set in: to provide an economical method of passenger transport in sections of light traffic where train service was infrequent.

(b) After road competition set in: (1) to counteract road competition; (2) to foment travel by affording a more frequent service at minimum of cost.

C) Buenos Ayres and Pacific Railway. — Recovery of lost traffic.

D) **Government General of Chosen, Railway Bureau.** — To make frequent service and obtain higher speed in local and sub-urban passenger traffic.

QUESTION 2. — *What was your secondary reason and any other reasons you may have had?*

A) **Reading Co.** — See answer to No. 1.

B) **Entre Rios.** — (a) It has been found that the travelling public show a marked preference for motor coaches over trains;

(b) Stops between stations to make rail travel more attractive through the medium of convenience.

(c) Greater acceleration of motor coaches favourable to (b).

C) **Buenos Ayres & Pacific.** — More economical operation.

D) **Govt. Gen. of Chosen.** — To reduce operating expenses.

QUESTION 3. — *What was the major economy anticipated?*

A) **Reading Co.** — Reduction of operating and maintenance costs.

B) **Entre Rios Ry.** — (a) With steam coaches — avoidance of assistant guard.

(b) With I. C. railbuses — elimination of fireman and assistant guard.

(c) Reduction in fuel consumption.

(d) Lighter track wear and coach maintenance.

C) **Buenos Ayres & Pacific.** — Reduction in expenditure on fuel and wages.

D) **Govt. Gen. of Chosen.** — No data.

QUESTION 4. — *What were the secondary economies anticipated?*

A) **Reading Co.** — Reduction in engine house expenses.

B) **Entre Rios Ry.** — See reply to Question 3.

C) **Buenos Ayres & Pacific.** — Reduction of maintenance expenses.

QUESTION 5. — *What was the major service improvement anticipated?*

A) **Reading Co.** — The most important service improvement anticipated was the ability to furnish more frequent service with the gas-electric cars on account of the lower cost per train-mile compared to steam service.

B) **Entre Rios Ry.** — Greater frequency of service.

C) **Buenos Ayres & Pacific.** — Improved timings, higher speeds.

D) **Govt. Gen. of Chosen.** — See reply to Question 1.

QUESTION 6. — *What were the secondary improvements expected?*

A) **Reading Co.** — The fact that with the less expensive operation of gas-electric cars, it was possible to maintain some form of service on branch lines, whereon it was impossible to continue the more expensive steam service.

B) **Entre Rios Ry.** — (a) A more popular service.

(b) Facility of lifting passengers at small villages and level crossings situated at distances from stations.

C) **Buenos Ayres & Pacific.** — More frequent services.

D) **Govt. Gen. of Chosen.** — See reply to Question 1.

QUESTION 7. — *What was the relative order of importance of economy and service? In other words, which of the two do you regard as of primary importance and which of secondary importance, or do you consider the two so involved with each other, as regards other than rail forms of competitive transport that it is not possible to separate the two factors, deeming it ad-*

visible to combine them into one factor, jointly including both commercial and operating efficiency?

A) **Reading Co.** — It is felt that the questions of economy and service were so involved with each other, as well as the other forms of rail transportation, and with competitive transportation, that it is not possible to separate the two factors.

B) **Entre Rios Ry.** — Service improvements first and economy in operation second.

C) **Buenos Ayres & Pacific.** — Economy and service are definitely interrelated.

D) **Govt. Gen. of Chosen.** — Service given the first consideration.

QUESTION 8. — *What is the commercial relationship between your passenger and freight services?*

A) **Reading Co.** — The commercial relationship between our passenger and freight services cannot be definitely defined, but in certain industrial centers it has been felt that the maintenance of an adequate, dependable and efficient passenger service had some effect in influencing the freight traffic on our line.

B) **Entre Rios Ry.** — Only in that shippers accustomed to use the rail route in preference to road and river are naturally influenced through acquaintanceship to consign their goods by railway.

C) **Buenos Ayres & Pacific.** — On our system, passenger service is purely complementary to freight service, as, apart from Buenos Ayres local passenger service, a skeleton service only is maintained on other parts of system, sufficient to enable traders to effect business. Hence freight service has to support passenger service.

QUESTION 9. — *To what extent do your passenger and freight services directly and indirectly support each other, and what are the reasons involved?*

A) **Reading Co.** — It cannot be said that either the freight or passenger service directly support each other, although in some cases passenger service is operated which does not produce sufficient revenue to pay the out of pocket cost, but this business is, of course, supported on the revenue from freight traffic. The passenger service referred to is operated through necessity in order to provide adequate frequency and give a more rounded service.

B) **Entre Rios Ry.** — It is not possible to gauge the extent, as the tariffication aspect is so strong (owing to the unlimited liberty of rate adjustment enjoyed by road and river competitors against very restricted powers allowed to railways in this connection) that the influence referred to under Question No. 8 is merely of relative value.

C) **Buenos Ayres & Pacific.** — See reply to Question 8.

QUESTION 10. — *Which of the three factors — weight, speed and service flexibility — do you regard as the most important, and what is the proportional relationship of the other two, and why?*

A) **Reading Co.** — Service flexibility is most important, and requires both weight and speed. However, there are certain classes of service where speed is a primary factor. Of 17 rail motor cars in operation, 15 operate first-class trains.

B) **Entre Rios Ry.** — Flexibility of service is the most important, owing to the elementary stage of development in the zone served, followed by speed required for competitive services, and lastly weight, which is also a factor of importance owing to the poor quality of track in many sections of the line.

C) **Buenos Ayres & Pacific.** — Service flexibility is the most important, speed comes next, then weight. Not possible assign proportional relationship from experience to date.

D) **Govt. Gen. of Chosen.** — Service flexi-

bility is the most important, speed is the second, and then weight.

QUESTION 11. — *What is the proportional relationship of service and cost of service, and why?*

A) Reading Co. — There is no fixed proportional relationship between service and cost of service. No general service has borne a closer relationship than the volume of traffic or revenue, the service afforded being in proportion to the traffic offered. On certain lines service is provided irrespective of traffic offered, in order to provide necessary frequency to give complete schedules.

B) Entre Rios Ry. — This depends on intensity of competition. Where conditions are severe, cost of operation can approximate the results of service as long as competition is displaced or even kept within bounds thereby. Where conditions are less exacting, the cost of operation must be kept in holding with: (1) the encouragement of extra traffic; (2) the exclusion of the entry of new competitors into the zone of action.

C) Buenos Ayres & Pacific. — Experience to date not sufficient to give definite reply.

QUESTION 12. — *As regards the motive power unit, which of the two factors — prime mover or transmission — have you found gave you the most trouble, and why? State kind of trouble encountered and steps taken to remedy it.*

A) Reading Co. — Since cars operated are gasoline-electric and oil-electric motor car type, in which motors are employed for traction, the prime mover (engine) gives the most trouble. Have not experienced any extraordinary troubles with electrical or mechanical portions of the equipment. Delays and breakdowns due to failed parts, etc. are kept to a minimum through regular inspections, tests and general overhaul, based on daily, monthly, and mileage basis. Repeated failures of parts are investigated, steps taken to improve the condition with the use of parts

better adapted for the service and requirements. In cases of man failures, through proper instructions.

B) Entre Rios Ry. — Experience is distributed between:

(a) Steam railcars;

(b) Road vehicles converted into rail vehicles;

(c) A light railcar running on rubber tyres having Noble guide discs and with petrol motor.

(a) 1. Steam railcars having engine, boiler and cabin mounted on short wheel base bogie forming a power unit articulated with saloon body.

These cars have shown tendency to excessive pitching and hunting of power unit, in running over light unballasted track with worn rail joints, which causes severe racking of structural components and somewhat heavy wear and tear on engine. A number of engine failures have been recorded, but these may be attributed largely to lack of experience, with a type of engine with which the operating and repair staff were unaccustomed.

Operation, repair and adjustment call for a degree of delicacy not readily recognised by normal steam locomotive personnel, and training in new conditions is indicated.

Transmission of these cars is by chain drive from crank or jack shaft to driving axle. These driving chains stretch and are liable to rather rapid wear. Grease lubrication has to be used and as chains are unprotected, they accumulate dirt and grit. Very careful attention to adjustment is necessary.

(a) 2. Later cars are fitted with six cylinder single acting reversing engines slung from coach underframe with cardan shaft connection to final drive assembly on driving axle consisting of bevel gearing with spur and pinion. These cars have maintained an excellent record in service, both engine and transmission proving free from any serious trouble. Experience gained on earlier cars has no doubt helped to achieve good results

but the engine and transmission system is undoubtedly superior. These cars are articulated, running on three bogies of somewhat short wheel base (7' 0" and 6' 6"). These bogies have proved liable to breakage of light components and to loosening of rivetted members.

(a) 3. An articulated car with boiler and vertical engine mounted on power bogie, over which the body underframe is centrally pivotted, has not proved so successful. Transmission is by gearing from crank shaft, through an intermediary shaft, to a jack-shaft provided with cranks carrying connecting rods to coupled bogie wheels. Pitching and hunting of the power bogie is excessive. In spite of considerable « nursing », engine and transmission failures have been frequent. In one case the crank shaft failed. In other cases the origin has been obscure, but the lubrication system has not proved too reliable. It has now been decided to fit this vehicle with C. I. engines and mechanical transmission.

(b) These vehicles consist of ordinary road lorries converted to run on rails by the simple expedient of fitting built-up wheels having light steel railway tyres, the original wheel centres and axles being retained, but where necessary, roller bearings to take the more severe side thrust conditions have been fitted. Engines are of a type well proved on the road and have given satisfaction generally, though the high average power developed results in more rapid burning of valve seats.

These cars have completed considerable mileage, with milk and vegetable traffic and also have accommodation for passengers. They have proved capable of hauling a light trailer.

One car provided with an omnibus type body suffered failure of a front axle. Axles as fitted to road vehicles are unlikely to prove satisfactory under the more severe rail conditions and the danger involved can best be avoided by the fitting of more suitable axles.

These conversions were made to vehicles available at hand, to carry out experimental services and have sufficed to obtain valuable experience at comparatively low cost, but cannot be considered to offer sufficient security or commodity for permanent adoption.

Vehicles of this capacity, if considered advantageous or suitable for specified services, could be constructed by mounting the road lorry power unit and gear-box in a more orthodox railway chassis, incorporating the advantageous features of road vehicle design whilst eliminating such features as are unnecessary and inconvenient in application to the rail vehicle, with a body to suit the service contemplated. The differential gear could be suppressed in final drive and a reverse substituted, giving either direction running if required.

On these railways measures are being taken to provide more suitable axles in order to give more security in running during the remaining useful life of these vehicles.

An important feature of such light vehicles is the provision of adequate braking.

(c) This vehicle, delivered for trial purposes, has suffered a number of failures, and in consequence has only a low mileage credited. The power unit fitted although successfully employed in road car service, has proved incapable of withstanding the more arduous working conditions involved in a rail vehicle. Transmission is by a standard gear-box, with nominal reverse suppressed, dual-directional running being obtained from a reverse gear assembly between change speed gear-box and final drive which is carried through to both axles of driving bogie. This reverse gear-box has also given trouble. Several failures have been due to clutch linings « burning » out.

The rubber tyres of cushion type limit the wheel load to approximately one ton, the loaded weight of this bogie vehicle being under eight tons.

This weight restriction practically imposes a very short wheel-base to the four-wheel bogies. On a damp or wet rail excessive

slip has been noted reducing speed to 20 miles per hour. Under these conditions braking, quite good on a dry rail, becomes inoperative. There have been indications that considerable slip occurs during running on a dry rail, but this has not been proved definitely.

The rubber tyres, in combination with the guide discs, taking the place of the usual tyre flange, have not given the comfortable and smooth riding qualities hoped for. Trials have been limited to a stretch of badly worn track and the spring suspension provided has failed to damp out road shocks, and intermittent contacts of the guide discs with the rail produce side shocks which detract from riding comfort.

In view of the frequent failures, proposals are on foot to replace the petrol engine by a compression-ignition engine of sturdy design and convert to a two-axle vehicle carried on normal flanged tyred wheels.

C) Buenos Ayres & Pacific. — Final drive element of transmission has given most trouble. Experience proves unsuitability of worm drive. Standardizing on bevel or double reduction drive for cars up to 300 B.H.P.

D) Govt. Gen. of Chosen. — Both gave us about the same trouble at first, but now we meet with very little trouble. The main troubles were as follows: piston, bendix drive spring, clutch disc, gears.

QUESTION 13. — *What suggestions have you to offer as regards improvement of the two factors mentioned in Question 12?*

Reading Co. — The Reading Railroad policy to keep to a minimum cars out of service on account of electrical or mechanical failure is through the adoption of regular inspection and test periods.

Entre Rios Ry. — For steam or internal-combustion power units a chain drive is not to be recommended.

The cardan shaft drive appears to be perfectly satisfactory, and is applicable to the axles of bogies having considerable pivoting

motion, with power unit fixed to vehicle underframe.

In a rail vehicle it should be appreciated that the power unit is working under power demand conditions incomparable with a road vehicle and more nearly approaching those of a motor boat or electric generator. The unit selected should be of robust design, capable of developing required power at moderate speed, and having a generous power margin.

It would be unwise to select any of the ultra light units constructed for road vehicles on the grounds that they have proved reliable in that application, without ensuring that the average power demand will be approximately equivalent.

The higher mileage usually possible on the rail reduces the periods between necessary overhauls and if the working conditions impose heavy wear and tear the nature of the overhaul work is liable to become embarrassing and liability to failure will increase.

C) Buenos Ayres & Pacific. — Substantial design based more on railway than road practice.

D) Govt. Gen. of Chosen. — The mechanical transmission adopted by us now is a simple method for smaller capacity, but unsuitable for heavy service.

* * *

QUESTION 14. — *By what methods do you test your railcars in order to compare them to one another and ascertain their characteristics (aerodynamic coefficient, running coefficient; efficiency of the transmission, of the gear box; gradient climbing ability, accelerative aptitude? What are the characteristic coefficients arrived at?*

A) Reading Co. — Motor cars are tested, after going through repair shops, for engine output, by giving them a standing load test with the use of the water barrel, through which generator can be loaded and the voltage and amperage curve ratings may

be determined; in this manner corrections are made to maintain the rated output.

B) Entre Rios Ry. — No methodical or standardized tests have been made with the object of collecting data as indicated. In general, average performance having been ascertained, the running schedule is adapted to suit.

C) Buenos Ayres & Pacific. — Number of cars so far in operation does not permit purchase of expensive testing equipment. This may have to be considered in the future.

D) Govt. Gen. of Chosen. — We have no test plant.

QUESTION 15. — *In view of your studies or experience to date, what suggestions have you to offer for improvement in general design, framing and body design, trucks, brakes, heating and ventilation, etc., of automotive power equipment, either car or locomotive?*

In other words, what are your present tendencies as regards new orders? What sort of operating requirements are they expected to meet?

A) Reading Co. — Underframes of integral cast steel or welded construction. Body of steel, structural frame, steel sheathed with plywood or aluminium lining and trim.

Trucks, cast steel with individual truck brake. Heating to be steam heat with an oil-fired heating unit.

B) Entre Rios Ry. — No suburban service exists on these railways to warrant such consideration.

Low tare weights are usually called for, but strength has to be maintained. The nature of the divers strains and stresses imposed in service need to be studied to arrive at the most efficient design. Rivetted joints should be avoided wherever possible by adoption of welding, and welding technique needs to be of the best.

It appears doubtful that satisfactory service and life will be obtainable from very light construction, as has proved practicable

in road vehicles, as the shocks which have to be absorbed are more severe generally. Weight reduction can be achieved by utilization of special materials now available.

Trucks or bogies, and more particularly the power bogies, are subject to severe strains and need to be of sound design and construction well braced against distortion. For comfortable riding and to reduce destructive shocks to the vehicle body, spring suspension and cushioning requires careful consideration. Periodicity of spring gear needs consideration to avoid synchronization of spring oscillations with the passing of rail joints. The incorporation of shock absorbers or snubbers in use in automobile practice could be of assistance in damping excessive oscillation.

On light railcars very efficient braking is essential and the system adopted should avoid possibility of any one defect causing complete failure.

C) Buenos Ayres & Pacific. — (a) Existing railway practice is no guide.

(b) Body and underframe should be designed as one unit.

(c) Truck or bogies, particularly when carrying motive power, require careful design. Springing vitally important.

(d) Braking must be on a high standard. Retardation rates must be commensurate with higher acceleration rates to obtain high schedule speeds.

(e) For really high-speed work streamlined form demands some measure of air conditioning.

(f) Operating conditions for future expected to be sustained speeds of 120 kilometres per hour for long distances under semi-tropical to temperate conditions at altitudes ranging up to 3500 feet.

D) Govt. Gen. of Chosen. — Nothing special to be mentioned.

QUESTION 16. — *Please attach a short description of your most recent designs of railcar or motor train and supply, if possible, interior and exterior photos, diagrams, etc.*

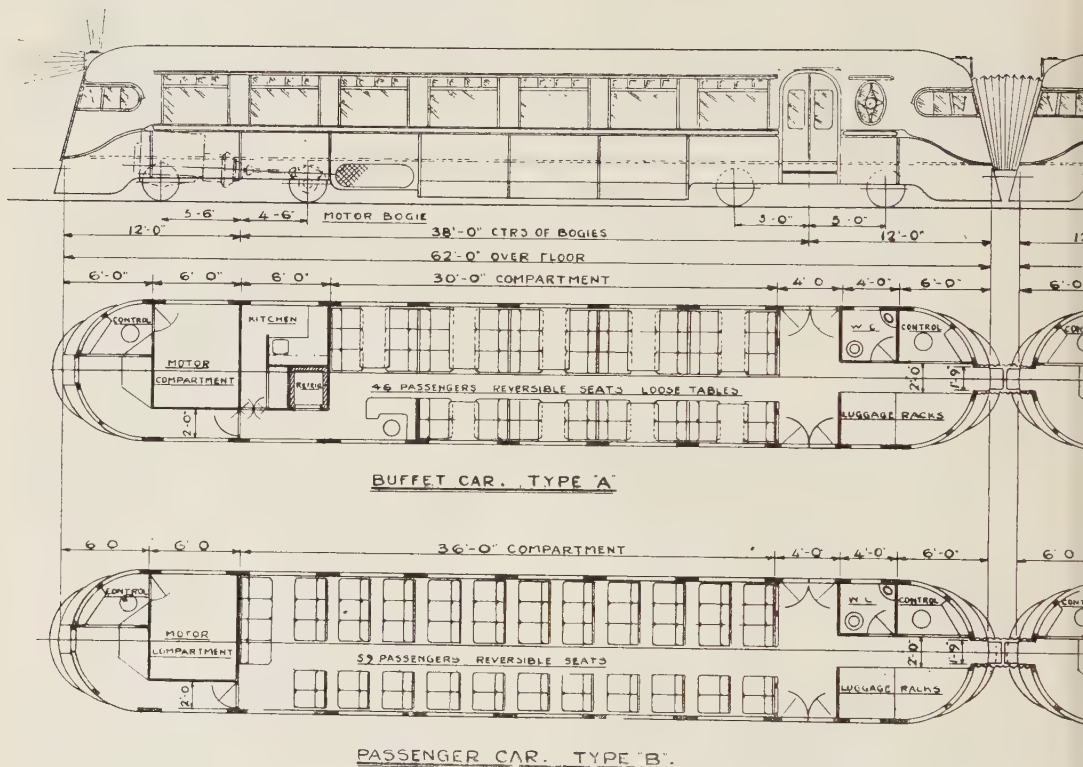


Diagram showing the types of
Buenos Ayres

A) **Reading Co.** — We do not have on this road the latest, modernistic design of equipment which has recently been developed, commonly known as streamlined trains, since last car was purchased in the year 1929.

B) **Entre Rios Ry.** — The railcars now building are destined to replace provincial and branch line steam trains and will provide an augmented and more rapid service. As they will operate on runs exceeding 200 kilometres in some cases a small buffet has to be provided. Arrangements have been made for blanking off this feature on runs where not required.

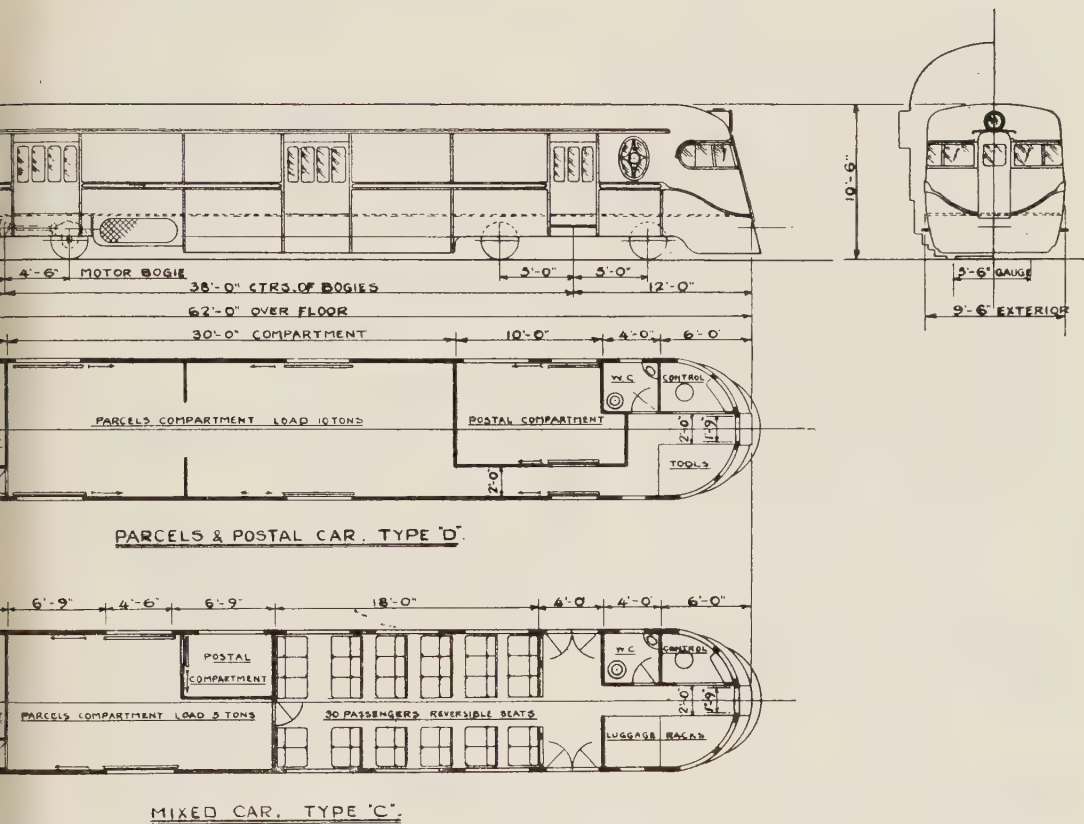
Accommodation for 1st and 2nd class pas-

sengers is provided, also space for luggage and parcel traffic, whilst a small postal compartment has also had to be incorporated.

Arrangements are also under way for the provision of a number of small rail buses seating 40 passengers and with a small compartment to carry two or three tons of country products.

These vehicles will provide services connecting the larger centres of population with the rural districts, experience with the converted road vehicles having shown that such services can be developed into profitable undertakings.

C) **Buenos Ayres & Pacific.** — Up to date



comprised in the railcar scheme.
Pacific Railway.

only light weight experimental railcars designed and built in the Railway Company's workshops have been operated. Tentative schemes have been prepared for railcar trains under multiple control for long-distance and branch-line work. Each car would have its own power plant of 250-300 B.H.P. Communication between cars would be only for train crew or passengers in case of emergency. The diagrams on this page give proportions and layout of types of cars comprised in the scheme.

QUESTION 17. — Has any consideration been given to a multiple-unit system of diesel-electrification of suburban trains? For

example: A railway operating one hundred 80-ft. light steel suburban cars, maximum length of suburban train run 40 miles, shortest 8 miles, the car underframe embodying trusses of light welded steel construction such as will permit the carrying of four 75 to 125-H.P. diesel-electric power plants, each plant supplying current to one traction motor. The power plants and motors controlled by an electric remote multiple-unit control system having a central control box on each car, a master controller on the panel of each end vestibule; control jumpers between the cars, with the whole system of control so arranged that the starting, idling, and speed

control of all power plants will function automatically according to the contactor positions of any one master controller. No current flows to traction motors when the engines are idling.

In case any one engine fails to start, the relay design is such that the starting position of the master controller may be again established without stopping the engines already idling; each power plant, however, will have its manually operated cut-out switch — the reverse direction of motor rotation obtained by reverse relay in the central control box.

The diesel engine for such service is of comparatively high-speed design, the fuel distributed at low pressure through a distributor to insure uniform distribution of the fuel to all cylinders, the fuel gasified in the head before released into the combustion chamber of the cylinder, etc... — the under-frame supported by two 4-wheel bogie trucks, one at each end of the car, each axle driven by a traction motor. The passenger-carrying body of the car supported by shock absorbers between the body and the under-frame which carries the driving gear.

A), B), D). — No.

C) Buenos Ayres & Pacific. — (a) System of multiple control has been considered for local service conditions and trial application of principle is being developed.

(b) Control has been considered for both mechanical and hydraulic transmission.

(c) Automatic couplers embodying all control would be employed.

QUESTION 18. — *What is the proportionate economic relationship between operation and maintenance?*

A) Reading Co. — Unable to make any comparison between the latest type equipment of this nature, namely streamlined, etc., as compared to the type of such equipment now in operation on the Reading Railroad. However, the relationship between operation and maintenance for the year 1935

of all our motor and trailing cars is as follows:

	Total.	Cost per car-mile.
Cost of operation . .	\$ 258 058	\$ 0.465
Cost of maintenance .	\$ 59 728	\$ 0.107

B) Entre Rios Ry.:

	Argentine paper.
Average locomotive maintenance cost per mile	\$ 0.408
Working cost of steam-hauled train per mile	\$ 1.030
Average maintenance cost of steam railcar (excluding coach-work) per mile	\$ 0.2109
Working cost of railcar-mile . .	\$ 0.699

These figures are given with the greatest reserve as it is felt that, used for comparing the economic relation between normal steam trains and self-propelled vehicles, they can be most misleading. Apart from the large difference in the potential carrying capacity provided, locomotive costs are taken over a period of effort to make up arrears in maintenance, whilst railcar services are dependent upon the cars available; in the majority of cases a steam train is utilized whilst a railcar is under repair.

C) Buenos Ayres & Pacific. — Based on several years' operation of two experimental railcars, of which close records were kept, the relationship between operating and maintenance expenses is as follows:

Operating	75 %
Maintenance	25 %

D) Govt. Gen. of Chosen. — The economic ratio between maintenance and operation is 1 to 3.5.

* * *

QUESTION 19. — *Can you supply full details as regards the total working-cost price of the railcar-mile or motor-train-mile on your System, stating separately the expendi-*

ture on amortization of the first cost and on operation, the latter item being again subdivided as shown hereafter?

A) **Reading Co.** — See statistics for the year 1934, pp. 868/12 to 871/15 hereafter.

B) **Entre Rios Ry.** — The working cost of the railcar-mile is \$ 0.699, Argentine paper.

C) **Buenos Ayres & Pacific.** — Based on the same as in reply to Question 18 and expressed in Argentine pesos (paper), the average total costs are as follows:

Total cost	\$ 0.565 per mile
Operation	\$ 0.309 » »
Depreciation and interest	\$ 0.15 » »

QUESTION 20. — *How does this working-cost price compare with that entailed by the corresponding steam-hauled train*

A) **Reading Co.** — No figure available for comparison with corresponding steam-hauled train.

B) **Entre Rios Ry.** — The working cost of the steam hauled train per mile is \$ 1.03, Argentine paper.

C) **Buenos Ayres & Pacific.** — Equivalent steam train costs to the foregoing are as follows:

Total cost	\$ 2.14 per mile
Operation	\$ 0.90 » »
Depreciation and interest	\$ 0.39 » »

QUESTION 21. — *What is the ratio of wages divided between wages for operation and wages for maintenance; and cost of fuel, cost of lubrication, etc.*

Give brief description of the engine or prime mover — kind of fuel — type of transmission, etc.

A) **Reading Co.:**

Year 1935.

Wages — Operation.	\$ 77 129
Wages — Maintenance	Not available
Total cost of fuel	\$ 33 533
Total cost of lubrication	\$ 2 880

Reading Company motor cars range from 250 to 600 H.P., and have been placed in service during years 1925 to 1932 inclusive. These cars are powered by single, double, and triple power units, each consisting of six cylinders, the prime mover in all cases being connected to the main generator by flexible couplings, main generator supplying the direct current to traction motors for propelling same. The engine speed is controlled by electro-pneumatic throttle. The series-parallel and shunt-wound traction motor connections are controlled by the throttle and operating levers through a system of electro-pneumatic contacts properly connected and protected for sequence of operation.

See hereafter specifications for lubricants and fuel. On all Reading Company motor cars electrical transmission in used.

A. — Specifications for cylinder oil for gasoline motors.

Scope. — Grade A-1. — These specifications cover three grades of oil: Winter oil for lubrication of cylinders of all types of motor cars, tractor shovels, burro cranes, track machines, ballast cleaners and air compressor gas engines from October 1st to April 1st.

Grade B. — Summer oil for the lubrication of the motors named under Grade A from April 1st to October 1st.

Grade C. — Special oil for the lubrication of motors of ballast cleaners during extreme hot weather.

Material desired. — 2. The materials desired are the products of refined petroleum oils, unmixed with fatty oils, resins, soaps or other compounds not derived from crude petroleum, having a specific gravity of 28 degrees Baume to 30 degrees Baume at 60 degrees Fahrenheit and a viscosity at 210 degrees Fahrenheit for the different grades as follows:

Grade A. —	65 seconds.
Grade B. —	75 seconds.
Grade C. —	100 seconds.

Re

Question 19. — Cost of operation and maintenance, and perform

1	Car number	65	66	67	68	
2	Type	Westing-house Cummins Diesel	Brill Hall-Scott Westing-house	Brill Westing-house	Brill Westing-house	Brill Westing-house
3	Length	50' 1"	73' 0"	73' 0"	73' 0"	73' 0"
4	Number engine units	1	2	2	2	2
5	Horse-power	125	600	500	500	500
6	Date placed in service	12-2-32	5-12-30	6-5-29	6-1-29	7-1-29
7	Serviceable days — assigned	141	284	164	174	284
8	» — unassigned	119	77	118	13	77
9	Unserviceable days	105	4	83	178	105
10	Per cent availability	57.32	98.61	66.40	49.43	57.32
11	Hours in service	991	1 899	1 383	1 494	2 400
12	Motor-miles	18 696	30 665	22 513	25 121	33 900
13	Trailer-miles	0	50 429	28 588	1 658	31 300
14	Total car-miles	18 696	81 094	51 101	26 779	65 200
15	Total ton-miles	218 743	4 988 392	3 048 146	1 971 999	4 945 300
16	Motor cars — Int. on investment . . \$	2 410.00	4 068.77	3 938.28	3 826.49	3 900.00
17	» — Depreciation \$	980.07	1 654.63	1 601.57	1 556.11	1 600.00
18	Crews wages \$	3 322.10	5 519.08	4 961.04	4 461.00	6 200.00
19	Cost of fuel \$	172.00	4 773.98	3 070.55	3 165.00	4 400.00
20	Cost of lubricating oil \$	93.00	158.03	134.68	237.00	300.00
21	Cost of supplies \$	17.00	85.84	110.54	37.00	100.00
22	Cost of motor-car maintenance . . . \$	2 706.34	1 446.93	2 739.73	4 390.37	6 000.00
23	Cost of maintenance per motor-mile . \$	0.1447	0.0472	0.1216	0.1747	0.1747
24	Total cost of motor-car operation . . \$	9 700.41	17 707.26	16 556.39	17 672.97	22 800.00
25	Cost of operation per motor-mile . . \$	0.5188	0.5774	0.7354	0.7035	0.7035
26	Trailers — Int. on investment . . . \$	...	3 646.39	3 225.79	127.00	1 700.00

pany.

asoline-electric and oil-electric railcars for the year 1934.

70	73	74	75	76	77	78	79	80
Westinghouse Diesel	Brill Hall-Scott Westinghouse.	Westinghouse Diesel	Brill Winton Westinghouse	Mack Westinghouse	Brill Westinghouse	Brill Westinghouse	Brill Westinghouse	Brill Westinghouse
73' 0"	73' 0"	73' 0"	73' 0"	73' 0"	62' 2 1/2"	62' 2 1/2"	62' 2 1/2"	60' 0"
1	2	1	2	3	1	1	1	1
330	600	330	330	360	250	250	250	250
10-2-29	3-12-29	7-1-29	2-2-28	1-22-29	4-24-27	4-24-27	4-24-27	8-19-25
118	202	109	235	78	196	158	162	251
20	36	19	43	228	141	192	150	53
227	127	237	87	59	28	15	53	61
34.20	61.40	31.50	72.98	56.93	87.50	91.33	75.35	80.45
1 091	1 790	1 093	2 184	778	2 771	2 591	2 041	2 187
7 451	30 542	17 524	29 862	6 780	37 171	34 855	22 048	30 224
17 505	45 204	17 357	0	0	0	0	0	0
34 956	75 746	34 881	29 862	6 780	37 171	34 855	22 048	30 224
64 443	4 506 481	1 765 416	2 060 478	454 260	1 821 379	1 707 893	1 080 352	1 360 080
3 719.25	4 022.78	3 735.33	3 359.77	3 549.48	2 451.21	2 451.23	2 451.76	2 318.54
1 512.50	1 635.93	1 519.05	1 366.31	1 443.46	996.83	996.84	997.05	942.87
3 874.00	6 670.46	3 787.74	5 876.02	1 907.00	6 825.77	6 311.61	4 997.38	6 658.19
464.00	4 532.63	358.96	3 074.75	690.00	2 276.62	1 903.73	1 357.40	1 535.40
261.00	158.21	242.74	500.58	77.00	189.06	200.22	140.38	156.73
13.00	39.39	8.19	25.05	9.00	17.73	15.77	11.62	13.21
4 024.98	4 137.07	1 620.71	2 624.47	3 250.61	4 315.94	2 235.70	4 244.52	2 839.77
0.2306	0.1354	0.0924	0.0876	0.4794	0.1161	0.0641	0.1929	0.0939
3 868.73	21 196.47	11 272.77	16 826.95	10 926.55	17 073.16	14 115.10	14 200.41	14 464.71
0.7947	0.6940	0.6432	0.5634	1.6115	0.4593	0.4049	0.6140	0.4785
1 517.01	3 403.01	1 510.62	...	...	...	...	...	...

1	Car number	65	66	67	68	
2	Type	Westing-house Cummins Diesel	Brill Hall-Scott Westing-house	Brill Westing-house	Brill Westing-house	
27	Trailers — Depreciation \$	...	1 482.76	905.11	51.63	
28	Cost of trailer-car maintenance . . . \$	...	674.80	300.22	17.58	
29	Total cost of maintenance of motor and trailer-cars \$	2 706.34	2 121.73	3 039.95	4 407.95	6
30	Cost of maintenance per car-mile . . \$	0.1447	0.0261	0.0594	0.1646	
31	Cost of maintenance per ton-mile . . \$	0.012326	0.000425	0.000997	0.002235	
32	Total cost of operation of motor and trailer-cars \$	9 700.41	23 511.21	19 987.51	17 869.18	25
33	Cost of operation per car-mile . . . \$	0.5188	0.2899	0.3911	0.6672	
34	Cost of operation per ton-mile . . . \$	0.014346	0.004713	0.006557	0.009061	
35	Fuel — gallons	4 080	48 346	28 502	31 347	44
36	» — motor-miles per gallon	4.58	0.63	0.79	0.80	
37	» — car-miles per gallon	4.58	1.67	1.79	0.85	
38	» — ton-miles per gallon	53.61	103.20	106.94	62.90	
39	Lub. oil — gallons	302	478	451	805	1
40	» — motor-miles per gallon . . .	61.90	64.15	49.91	31.20	
41	Avg. miles per assigned day	132.59	107.97	137.27	144.37	

Notes:

1. Motor cars Nos. 68, 70, 76 and 77 received general overhaul during 1934.
2. Motor car No. 65 is equipped with pneumatic tires.
3. Motor cars Nos. 71 and 72 assigned to and operating on P. R. S. L. and no figures submitted. These two cars were also overhauled during 1934.
4. Motor car No. 98 held in reserve, account not being required.
5. Line 9. Unserviceable days includes time out of service for general overhaul and carbon cleaning periods.
6. Line 10. Availability is derived by dividing Line 7 by the total of Lines 7 and 9.
7. Lines 16, 17, 26 and 27. Interest figured at 6 % and depreciation at 2.44 o/o.
8. Line 22. Cost of motor car maintenance includes labor and material for both running and shop repairs.

0	73	74	75	76	77	78	79	80
Westing-house Diesel	Brill Hall-Scott Westing-house	Westing-house Diesel	Brill Winton Westing-house	Mack Westing-house	Brill Westing-house	Brill Westing-house	Brill Westing-house	Brill Westing-house
616.91	1 383.78	614.32	...	...	...	...	...	...
116.99	509.99	115.95	...	...	...	...	...	...
141.97	4 647.06	1 736.66	2 624.47	3 250.61	4 315.94	2 235.70	4 244.52	2 839.77
0.1184	0.0613	0.0497	0.0878	0.4794	0.1161	0.0641	0.1925	0.0939
0.002347	0.001031	0.000983	0.001273	0.007155	0.002369	0.001309	0.003928	0.002087
119.64	26 493.25	13 513.66	16 826.95	10 926.55	17 073.16	14 115.10	14 200.11	14 464.71
0.4611	0.3497	0.3874	0.5634	1.6115	0.4593	0.4049	0.6440	0.4788
0.009135	0.005878	0.007654	0.008166	0.024053	0.009373	0.008264	0.013143	0.010635
264	38 854	8 430	29 988	8 390	26 100	24 374	16 607	20 065
1.70	0.79	2.08	0.99	0.80	1.42	1.43	1.33	1.51
3.40	1.94	4.13	0.99	0.80	1.42	1.43	1.33	1.51
171.90	115.98	209.42	68.70	54.14	69.78	70.07	65.05	67.78
753	428	835	1 775	283	643	702	492	566
23.17	71.34	20.98	16.82	23.95	57.80	49.65	44.81	53.39
147.88	151.19	160.77	127.07	86.92	189.64	220.60	136.09	120.41

9. Lines 26, 27 and 28. Cost of maintenance, interest and depreciation on trailer cars computed as follows:

Where specially built trailers were used, actual cost of these cars and actual maintenance figures were used.

Where regular passenger or freight cars were used, following figures obtained from accounting department were used:

Passenger cars: Maintenance per mile, \$ 0.0215. Interest per mile, \$ 0.0546. Depreciation per mile, \$ 0.0222.

Freight cars: Maintenance per mile, \$ 0.0113. Interest per mile, \$ 0.0190. Depreciation per mile, \$ 0.0076.

10. Line 28. Cost of trailer car maintenance includes labor, material and supplies for both running and shop repairs.

Average cost of operation per car-mile: \$ 0.4381.

Sampling. — 3. A shipment being received at any point, a sample of not less than one pint must be taken from each carload or less and sent by train service to the engineer of tests at Reading, Penna. The sample must be accompanied by a « Sample for Test Tag » properly filled out. In taking the sample, care must be exercised to prevent contaminating the sample with any other oil or any other substance, and a clean, dry container must be used. This sample will represent the shipment, and the material must not be used until report of test is received.

Method of test. — 4 Samples, as received at the laboratory, will be tested in accordance with the methods for testing petroleum products as contained in Part 2 of Technical Paper No. 323 B « Specifications for petroleum and methods for testing », issued by the U. S. Department of the Interior.

Rejection limits. — 5. Grades A, B and C oils will not be accepted if sample from shipment:

- (a) Flashes below 425 degrees Fahrenheit.
- (b) Fires below 490 degrees Fahrenheit.
- (c) Has a pour point above 35 degrees Fahrenheit.
- (d) Has an acidity requiring more than 0.40 mg. of potassium hydroxide to neutralize one gramme of oil.
- (e) If a clean copper strip is discolored when submerged in the oil for three hours at 212 degrees Fahrenheit.
- (f) If carbon residue exceeds 1.00 %.
- (g) Has a specific gravity of less than 28 degrees or more than 32 degrees Baume at 60 degrees Fahrenheit.
- (h) Has a viscosity at 210 degrees Fahrenheit for the different grades as follows:
 Grade A, less than 63 seconds or more than 68 seconds.
 Grade B, less than 73 seconds or more than 78 seconds.
 Grade C, less than 97 seconds or more than 102 seconds.

Rehearing. — 6. Samples of rejected material will be held one month from date of test report. In case the shipper is dissatisfied with the results of test he may make claim for a rehearing within that time. Failure to raise a question within one month will be constructed as evidence of satisfaction with results of test, the samples will be scrapped and claim for a rehearing will not be considered.

Freight charges. — 7. All rejected material will be returned to the shipper, who must pay freight charges both ways.

B. — Motor gasoline.

I. — General statement.

1. This specification covers the grade of gasoline used as a fuel for automobile and similar engines.

II. — Properties and tests.

2. Color. — The color shall not be darker than No. 16 Saybolt.

3. Corrosion test. — A clean copper strip shall not be discolored when submerged in the gasoline for three hours at 122° F.

4. Distillation range. — When the first drop has been recovered in the graduated receiver, the thermometer shall not read more than 55° C. (100 F.).

When 20 % has been recovered in the receiver, the thermometer shall not read more than 105° C. (190 F.).

When 50 % has been recovered in the receiver, the thermometer shall not read more than 140° C. (275 F.).

When 90 % has been recovered in the receiver, the thermometer shall not read more than 200° C. (385 F.).

The end point shall not be higher than 225° C. (420 F.).

At least 95 % shall be recovered as distillate in the receiver from the distillation.

5. All tests shall be made according to the methods for testing petroleum products contained in Part 2 of Technical Paper No. 323 of the U. S. Department of the Interior « Stand-

ard specifications for petroleum products and methods for testing ».

C. — Fuel oil specification for diesel engines.

1. Fuel oil shall be a straight overhead petroleum hydro-carbon distillate, free from grit, acid, and fibrous and other foreign matters likely to clog or injure the valves.

It shall not be a mixture of light oil and heavy residue.

2. Viscosity at 100° Fahrenheit shall be not higher than 50 seconds and not lower than 34 seconds, Saybolt Universal.

3. Flash point shall not be lower than 150° Fahrenheit (Tag closed cup method).

4. Fuel oil shall be free from water.

5. Sediment content shall not exceed 0.1 %.

6. Sulphur content shall not exceed 0.5 %.

7. Gravity at 60° Fahrenheit shall be not heavier than 27° Baume and not lighter than 32° Baume.

8. Pour point shall be not higher than 0° Fahrenheit.

9. Distillation :

No fuel oil to distill below 392° Fahrenheit.

392 to 455° F. 5 to 8 %

455 to 599° F. 70 to 75 %

599 to 675° F. 10 to 15 %

675 to 710° F. 3 to 6 %

No fuel oil to distill above 710° Fahrenheit.

Residue after completion of distillation shall not be tarry matter.

B) Entre Rios Ry. — Accurate separate costs have not been kept, so that any information given in answer to this query as also to No. 22 might be very misleading.

C) Buenos Ayres & Pacific. — Average figures are as follows for the wages bill for railcars :

Operation	\$ 0.185	per mile
Maintenance	\$ 0.0625	» »

The engines employed are of motor bus or

lorry type of British manufacture, giving 90-100 B.H.P. at 1700 r.p.m., 4-stroke; fuel, petrol of Argentine production. Transmission : mechanical; 4-speed gearbox. Separate reverse box. Final drive of worm type now being replaced by spiral bevel, double reduction.

Fuel costs \$ 0.089 per mile

Lubrication costs \$ 0.024 » »

QUESTION 22. — *What proportion of the maintenance costs are chargeable to running repairs, and what proportion to general repairs or general overhaul?*

A) Reading Co. — No division of costs made between maintenance and cost chargeable to running repairs, general repairs or general overhaul.

C) Buenos Ayres & Pacific. — Proportion of running and general repairs costs, approximately :

Running 58 %

General 42 %

QUESTION 23. — *What mileage is obtained between general repairs and general overhauls?*

A) Reading Co. — Cars are generally overhauled after 125 000 miles. Do not have general repair program, other repairs are made at the time required to keep cars in operation.

B) Entre Rios Ry. — Steam cars have completed 60 000 - 100 000 miles between general repairs, with running repairs effected in depots.

Petrol engined vehicles (converted road lorries) average 22 000 miles between general overhauls.

C) Buenos Ayres & Pacific. — Government certificate valid for 150 000 kilometres is obtained, which can be increased by 100 000 kilometres after intermediate light repair.

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QUESTION 24. — *What methods do you employ for instructing, qualifying and disciplining supervisors?*

A) **Reading Co.** — Maintenance is handled by the regular steam locomotive engine house forces and supervisors who are promoted along the lines of seniority and ability.

B) **Entre Rios Ry.** — Supervision of steam cars has been carried out by existing locomotive operating and maintenance staff.

Internal combustion units are under direct care of engineer with automobile training.

C) **Buenos Ayres & Pacific.** — Number of cars in operation is not sufficient to merit as yet separate organization. Present sub-sections of existing organization may possibly be merged in one if developments require it. This also applies to maintainers and operators (Questions 25 and 26 hereafter).

D) **Govt. Gen. of Chosen.** — As the construction and installation of the railcar is rather simple, supervisors, maintainers, and operators (Questions 25 and 26 hereafter) are selected from those concerned with steam locomotives disciplined practically.

QUESTION 25. — *What methods do you employ for instructing, qualifying and disciplining maintainers?*

A) **Reading Co.** — Maintainers consist of regular forces of mechanics and electricians who qualify from lower rated work on the same basis. Discipline consists of reprimand, followed by lay off and then dismissal.

B) **Entre Rios Ry.** — Steam car repairs carried out by selected personel from locomotive repair squads. Instruction in particular care required is given by supervisors and men not showing necessary aptitude are removed.

QUESTION 26. — *What methods do you employ for instructing, qualifying and disciplining operators?*

A) **Reading Co.** — The instruction and qualifying of operators is in charge of the

road foreman of engines as well as the supervisor in charge of equipment. In addition to the above, prospective operators ride the motor cars and under the guidance of the present motor car operator familiarize themselves with details relative to the branch of service.

B) **Entre Rios Ry.** — The staff undergo the regular government examination for steam train drivers.

QUESTION 27. — *Looking to the future, what do you consider the trend of developments, etc., and what do you anticipate as regards your own development, realizing as we must, that in view of the tremendous strides in engineering developments in all lines, we of necessity face many changes in all lines of human endeavour, not the least of which in all probability may be in the field of transportation?*

A) **Reading Co.** — Where conditions warrant the electrification of rail service is contemplated. Continuous development of door to door delivery with large strides in hauling trailers and containers on flat cars. The forwarding of mixed merchandise cars by rail in connection with truck pick up and delivery.

B) **Entre Rios Ry.** — As regards the future and in respect to our zone, motor coaches, either diesel or diesel-electric, possessing speed, comfort and economy of operation together with a moderate initial cost, appear to-day to be the ideal for the near future: (1) of small capacity for local services since, on the one hand, frequency of service is (and will be increasingly so) indispensable and, on the other, the density of population does not warrant big units; (2) of medium capacity but of greater comfort and reliability for long-distance journeys whilst, it must be remembered that for certain journeys between far distant cities, the advent of air transport may also bring a considerable competition in its train.

C) **Buenos Ayres & Pacific.** — The future

trend of development will, it is believed be on two lines:

(a) The replacement of existing steam passenger services by either articulated train sets with a leading power unit of sufficient capacity to enable a high average speed to be maintained, or the use of multiple unit trains, each unit of the train being provided with its own power plant. The choice of the type of train will depend not so much upon the relative technical merits of the two systems as upon the traffic density on the individual railways. For railways on which the passenger traffic is less dense, the second alternative seems to offer possibilities of greater flexibility and it is on these lines that developments on the B.A.P. Railway may be expected to proceed.

(b) Branch line or subsidiary services may be met by the provision of either standardized units which could, as required, form part of the main line multiple unit trains since the motive power equipment and control system would be completely standardized, or, alternatively, by the provision of lighter weight units of lower power specifically designed to meet these requirements.

It is likewise believed that not only passenger, but light cargo and parcels traffic should be considered as part of any scheme for the development of diesel rail services, since in many cases commodities of light weight urgently required are of vital importance to the commercial wellbeing of individuals and communities.

D) **Govt. Gen. of Chosen.** — Both will become important units in future.

QUESTION 28. — *What suggestions have you to offer for the more intelligent, effective and rapid development of methods and equipment for more effectively meeting the competition that will be incurred by the rapid and effective developments of our competitors?*

A) **Reading Co.** — Closer cooperative between rail and truck companies. Goal to be ultimate to co-ordination based on service

and economic factors. New development of equipment and service requirements must be followed up and tested, to provide competitive transportation.

B) **Entre Rios Ry.** — Organized and constant interchange of results of research experiments and experience between all systems faced with similar problems and working under comparable conditions would be most helpful and, where possible, meetings of specialized officers to receive practical demonstrations would assist a more rational development of policy and procedure.

C) **Buenos Ayres & Pacific.** — (a) Standardization of ideas as to lines on which railcar services should develop.

(b) Standardization of type of accommodation in any one country.

(c) Elimination of 1st and 2nd classes and adoption where necessary of luxury cars for which supplementary charge would be made.

(d) Standardization amongst railway engineers as to their specification of diesel engine power, thus permitting more specialized production.

(e) Pooling for benefit of all, of experimental data.

D) **Govt. Gen. of Chosen.** — Better service, improvement of facilities and equipment, low rates.

QUESTION 29. — *In particular, have you considered or do you anticipate giving consideration to a better transfer coordination of either or both freight and passenger traffic, between the rails and the highways and other competitive forms of transport, as regards all factors relative to both cost and service — if so, how and why?*

A) **Reading Co.** — Since 1928, have been actively working along the line of transfer co-ordination of both freight and passenger traffic by rail and highway, having 44 units for passenger service and 87 units for freight service on the highway.

B) Entre Rios Ry. — Consideration has already been given to a more extensive transfer coordination of both passenger and goods traffics, especially the latter, with road services — (1) as regards passenger traffic — by means of agreements with reliable road operating concerns with a view to capturing traffic to or from points without rail connection which at present is carried practically from door to door by road vehicles. (2) Goods traffic — by the same means and for identical reasons as (1) as also to incorporate a door to door service designed to meet road competition which, in so far as some of our local traffics are concerned, has, to its great advantage, such a service. At the present time the Argentine railway companies are jointly concluding the final details of an agreement of this nature with one of the largest carting and delivery organizations in Buenos Ayres.

C) Buenos Ayres & Pacific. — Railway and road services should be co-ordinated. Road services could be employed on main line work to feed railway and also supply service to less important points on railway, thus permitting longer distances between stops on railway.

D) Govt. Gen. of Chosen. — As competition between the rails and highways brings losses to both of them, the Government should grant licences for highway transportation only after very careful consideration.

QUESTION 30. — *Have you considered or do you anticipate giving consideration to a better coordination of either or both freight and passenger traffic between the rails and the highways, and other competitive forms of transport, by the use of equipment of a dual or multiple nature, such as, for example, an equipment which may be used in a manner somewhat similar to the « Articulated Universal Cargo Carrier » for freight traffic, as described on pages 722 to 728 inclusive of the Bulletin of the International Railway Congress Association, June 1935 number, and some form of a dual rail and*

highway passenger car, such as have been described in various publications? If so, how and why?

A) Reading Co. — Consideration has been given to this traffic problem, but due to clearance conditions the movement was not direct enough to afford any economies.

B) Entre Rios Ry. — The use of equipment of this class has been considered and initial experiments and trials were carried out with negative results due to the fact that the nature of traffic requiring such equipment is not sufficiently intense to justify its adoption and certainly insufficient to cover the cost of the return of containers to loading point where an unbalanced traffic is in question. A dual rail and highway passenger car, incorporating the Noble disc-guides, was also constructed and tried out and, in this case, again with negative results owing to operating difficulties which may in the course of time disappear.

C) Buenos-Ayres & Pacific. — The condition of roads in Argentina is as yet such that no consideration of a practical nature has been given to either of these proposals.

D) Govt. Gen. of Chosen. — No consideration has been given to a co-ordination of traffic between the rails and the highways, by the use of equipment of a dual or multiple nature.

* * *

E) Argentine State Railways.

The *Argentine State Railways* (Ferrocarriles del Estado Republica Argentina) supplied the following information.

The introduction of rail motor cars on this System is of too recent date for any results to be obtained, allowing of comparisons being made or conclusions of a technical or economic nature being drawn therefrom. It may be said, however, that as regards the benefit to accrue from the operation of these vehicles, and their consumption, they may

be expected to meet the objects which will justify their adoption.

The railcars are built by Messrs. Ganz & Co., of Budapest, to three different gauges: 29 to metre gauge, 2 to 4' 8 1/2" gauge and 3 to 5' 6" gauge. The interior equipment is adapted to the different parts of the System to which the vehicles will be assigned. They are of 5 different types.

The vehicles are of the non-articulated type, and have one motor bogie and one carrying bogie. An attempt has been made to standardize all structural parts, mechanisms and fittings as far as permitted by the three different gauges and the various interior equipments selected. Thus, for instance, the mechanical equipment described hereafter is absolutely identical for all the railcars. The vehicles are so designed that it will be possible to couple up all vehicles in pairs. To this end the headstocks carry a central removable panel which can be replaced easily by bellows and a gangway to give intercommunication between the two vehicles. When two railcars are coupled up the two engines working together, the engine of one of the vehicles will be pneumatically controlled from the other railcar.

Permissible speed.

The maximum sustained speed will be 100 km. (62 miles) an hour, it being possible to lower this speed — to suit the particular features of the zones wherein the vehicles are operated — by means of an adjusting device so designed that only the supervisory staff will be able to set it.

The weight of the standard-gauge railcars is 41 tons, and that of the metre-gauge vehicles, 35 tons.

Mechanical equipment.

This consists of a diesel engine and a mechanical transmission.

Engine. — Design: Ganz-Jendrassik, VI-a-R-170 6-cylinder 4-stroke type. — Bore 170 mm. (6 11/16"). — Stroke 240 mm. (9 7/16"). — Power at the normal speed of 1200 r.p.m.: 240 H.P. — Total cylinder swept

volume 32 685 cm³ (1 957 cu. in.). — Starting: by accumulators. — Fuel: heavy oil from the Government oil fields. — Automatic pressure lubrication.

Transmission. — The driving shaft transmits its torque to the gearbox through a universal joint, the gear wheels being of the straight normal type.

The gear wheels are engaged pneumatically from the driver's compartment for the different speeds by means of a clutch of the multiple disc (steel) type, while the first and second speeds can be thrown in by hand.

The reverse gear, also controlled by compressed air, is housed in the gearbox.

The gear wheels are of chrome-nickel case-hardened steel. All the gear wheel shafts run in roller bearings.

Transmission to the motor bogie axles is by means of cardan-joints and bevel gears. The latter are housed in casings which rest on the bogie axles in roller bearings and also rest on the bogie frame by means of articulated supports.

Engine cooling. — The engine is cooled by means of longitudinal radiators, the water being cooled by forced circulation produced by a centrifugal pump, and by the draught produced by two fans cooling down the water in the radiator piping.

The engine, gearbox and other details are mounted directly on the bogie with rubber joints in between.

Control gear. — The gearbox and reverse gear are controlled by compressed air, safety valves being provided, which absolutely prevent any misuse.

Each driver's compartment is equipped with the following devices: a push-button for starting; hand levers controlling the fuel admission; valves actuating the change speed gear and reverse gear; brake valves; hand brake wheel; a press-button for audible warnings; a press-button controlling the sanding gear; a key for the coach lighting and headlights; an electric engine speed indicator, oil pressure gauge for regulating

the pressure of the engine lubrication; two gauges showing the air pressure in the brake pipes and distant-control gear piping; a voltmeter showing the battery voltage; dead man's handle. Part of these devices are fitted on the driver's desk and the remainder on a suitably located board.

Bogies. — Each railcar has two bogies: a motor bogie carrying the equipment described above, both axles being driven; the other has two free axles.

The bogie frame is built of rolled steel sections assembled by electric welding.

The bogie centre bearings and side thrust blocks rest on rubber joints. The wheel tyres, 50 mm. (2") thick, are of high-tensile steel; the wheel diameter is 760 mm. (2' 5 7/8").

The axles are of high-tensile steel and the journals run in S. K. F. roller bearing boxes. The bogie spring gear consists of helical springs, each of which is made of 3 concentric springs, the cast steel supports of which are electrically welded to the bogie frame. The load of the springs is transmitted through rubber rings.

Frame. — This is built of chrome-steel rolled section assembled by electric welding.

The body frame, of chrome-steel rolled sections and pressings, is electrically welded to the main frame, the whole structure forming a box girder, a fact which was taken into account when calculating the latter.

Draw- and buffing gear. — This is of the Janney automatic type.

Brakes. — They are of the Westinghouse type, but were built by the Knorr Works. The Ganz air compressor is actuated directly by the transmission. The compressor is connected directly to the main reservoir, whence two independent circuits branch off, one for the brake, the other for the motor control. The air brake acts through the medium of the corresponding cylinder mounted on the car frame, on the eight wheels, two blocks braking each wheel.

A hand brake, which acts on all the wheels, is also available.

Railcar body.

Lining. — The body frame described above is sheathed on the outside with 2 mm. (5/64") steel plates, electrically welded to the framing. The interior lining is of 6-mm. (1/4") plywood.

The roof is finished in aluminium.

The floor covering is plywood with a cork and linoleum lining.

Door and windows. — The outside doors have a metal frame and panelling, with flaps covering the accesses made by the steps. The windows have frameless panes. They are fitted to the inside, are operated mechanically and slide down when opened. Louvred shutters are fitted to the outside. They consist of two hand-operated leaves and are raised when opened.

Luggage racks. — In the passenger compartments luggage racks run the whole length or the compartment partitions.

Seats. — These have a wooden frame and are leather-covered. In the upper class, arm rests are provided.

Mail compartment. — On one side of this compartment a sorting table is provided. Interior trimmings are similar to those in the passenger compartments.

Luggage compartment. — This compartment contains a folding table, an upholstered seat and a small cupboard. The floor is plywood.

Lavatories and closets. — Hygienic water closets, wash-stands and towel racks are provided.

Fittings. — All fittings such as locks, hand rails, lattice work protecting the front windows, lavatory fittings, towel racks, heating and ventilation control handles, ash trays, etc., are of chromium-plated brass.

Heating. — The railcars are heated by means of the engine cooling water which circulates in pipes fitted along the bottom part of the side walls of the passenger compartments, where they are arranged in two circuits. The heating is regulated by

means of valves suitably located in the driver's compartment.

Lighting. — Lighting is by means of a 1.2 kw. generator and a 180 amp.-hr. 24-volt battery. All compartments are lighted by lamps fixed to the ceiling. The regulation lights are carried on the outside of the railcar, including the headlight which also gives a vertical beam used for safety purposes when running at night.

The motor bogie can be lighted at will by means of two lamps conveniently located under the railcar, and also by means of a hand lamp. The lights in each compartment are wired into a circuit which is independent of the circuits feeding the other compartments. A switch in each circuit is fitted in the driver's compartment.

Kitchen. — In view of the traffic to be catered for by these railcars, the scheme embodies, a kitchen compartment in some of the types, mobile tables in sufficient numbers to cope with an ample buffet service being also provided. Such facilities will be available in particular in the standard and broad-gauge vehicles covering long distances.

The fuel used in the kitchen will be supergas, supplied by the Y. P. F. Cupboards to contain the necessary supergas bottles have therefore been fitted out in such vehicles.

II. — ROCK ISLAND « ROCKET TRAINS ».

Recently the *Chicago, Rock Island and Pacific Railway Company*, in conformity with its policy for improving transportation service for its patrons, contracted for six high-speed, lightweight, streamlined, 1 200-h.p. diesel-electric trains. In view of the very-high-speed service for which these trains were purchased, they have been aptly called « Rocket Trains » to distinguish them from the more conventional type of trains which have been common on our railroads for quite some many years; also to distinguish Rocket Ser-

vice from the slower and more conventional service.

Two of these trains are of the five-car type; each train consisting of one diesel-electric power car and four trailing cars. The other four trains are of the four-car type, each train consisting of one diesel-electric power car and three trailing cars.

The six diesel-electric power cars are being built by the Electro-Motive Corporation, La. Grange, Illinois, and the twenty trailing cars by the Edward G. Budd Manufacturing Co. Philadelphia, Pennsylvania.

The six diesel-electric power cars are identical in design. The prime-mover consists of a single E. M. C. 16-cylinder, V-type, two-cycle, 1 200-h.p. diesel engine, directly connected through a flexible coupling to a General Electric 600-volt direct-current generator. The power from the generator is delivered to the General Electric traction motors through a simplified control system. There are four of these traction motors, two of which are in the front four-wheel truck and two in the rear four-wheel truck.

The engine and generator, together with a Gardner-Denver mechanical air compressor driven from the engine generator shaft, are so located in the middle section of the power car above the floor as to afford easy access at all times for inspection and maintenance. Immediately forward of the power plant is the engineer's operating cab. The control equipment is so located that the engineer is seated in line with the high-vision windows essential to high-speed operation. Immediately forward of this operating cab, in the nose of the power-car, is placed the auxiliary and control equipment including necessary toilet facilities. In the rear section of the power-car, immediately after the power plant section are located two of the Vapor Company's latest type automatic, oil-burning boilers, each capable of delivering 1 200 lb., of steam per hour, afford-

ing sufficient capacity for heating the train under the most adverse weather conditions.

The power-car has a capacity of 980 gallons of diesel fuel, carried in tanks so located as to utilize space that would otherwise be wasted. Both the

diesel engine and the steam heating boilers use diesel fuel from one fuel supply system.

The following is an example of one of several fuel specifications which has proven satisfactory for this class of power equipment.

Flash (min.)	150° F.
Viscosity (S. S. U.) at 100° F.	35-70.
Viscosity (S. S. U.) at 32° F. (max.)	100.
Conradson, carbon (max.)	5.
Pour point in degrees F. (max.)	-
Water and sediment (max.)	0.1 %.
Ash (max.)	0.02 %.
Sulphur (max.)	0.5 %.
Cetane number (min.)	40.

It is desired that the fuel be free from any acid which in contact with any metal will form soap in sufficient quantities to plug up the fuel strainers.

The lubricating oil for the engine is circulated and distributed by means of a scavenger pump, taking the oil from the crank case, passing it through a filter and oil cooler to the oil supply tank from which it is taken by a pressure pump, the pressure in the distribut-

ing lines being regulated by a pressure relief valve which discharges into the crank case. These pumps are driven directly by the main engine and a device is provided to close the engine throttle in the event of a deficient oil supply.

The following is an example of one of the lubricating oil specifications which have been found to meet the requirements.

Saybolt viscosity at 100° F.	1 000 sec. max.
Saybolt viscosity at 210° F.	85-90 sec. min.
Flash	450° F. min.
Fire	500° F. min.
Pour	40° F. max.
Carbon residue	1.1 % max.
Sligh number	1 % max.
Evaporation — 5 hours at 150° C.	0.07 % max.

This must be a high-grade pure mineral oil made by a reputable oil company and must not be adulterated with any animal or vegetable matter, or with any metallic soaps. It is particularly important that it be entirely free from lard oil in any proportion. Asphaltum base oil is preferred.

The engine cooling system is so designed that the water supply tank is

located below the level of the radiator to permit automatic draining of the radiators when the engine is not running. All of the engine cooling system including fans, radiators, accessories, etc., are located in what may be called an attic section, thus assuring adequate cooling, together with clean air for the engine and at the same time provide ample head room in the engine compartment, leav-

ing ample space to facilitate the work of the inspector and maintainer.

There is sufficient tank capacity for 900 gallons of boiler water and provision has been made so that the supply may be quickly replenished from way-side water stations when found necessary to do so.

The power car's structure consists of a welded steel underframe, the wall or side section consisting of a Howe truss frame, making it necessary to use only light-weight curtain panels for the enclosure which permits finishing the outside of the power car to harmonize with the trailer cars.

The estimated weight of the power car is 210 000 lb. The estimated weight of three trailing cars ready to run is 238 530 lb. or a total train weight for a four-car train (including the power-car) of 448 530 lb. which is equal to a total train weight of 374 lb. per horse-power.

In the case of a five-car train (power car and four trailing cars) (the weight of the four trailing cars is 300 030 lb.), the total weight is 510 030 lb., equal to 425 lb. per horse-power.

The power car and the trailing cars all have standard height, floor and couplers, and can therefore be coupled to existing standard equipment.

These trains are of the semi-articulated type. In all of the six trains the power car not only supplies the power for hauling the train, but also supplies steam for heating and air for braking the train.

Since standard couplings are used, the power car may be uncoupled from the train in the same manner as steam locomotives are now uncoupled from the train. Therefore, at any time it may be necessary, a steam locomotive may be used in place of a power car. In this connection the electric current for lighting, air-conditioning, radio, communications, etc., is supplied to each one of the trailing cars by its own indi-

vidual Safety 20-kW. 64-volt body-hung generator, driven by a Spicer mechanical drive with automatic clutch in conjunction with a 500 ampere-hour storage battery.

In the case of the four-car train, the first and second trailing cars are articulated, having one truck in common. The first trailing car contains baggage, bar, dining, and coach facilities. The second trailing car is fitted up entirely as a coach. The third trailing car is an observation parlor car containing also lounge and coach facilities.

In the case of the five-car train, the first trailing car is similar to the first trailing car in the four-car train, and the second and third trailing cars are similar to the second trailing car of the four-car train. The fourth trailing car is similar to the third trailing car of the four-car train. It will therefore be noticed that the four and five-car trains are practically the same except that there is one more coach in the five-car train than in the four-car train. However the first, second and third trailing cars of the five-car train are articulated. In this connection it will be noticed that the rear car is not articulated in any of the trains, which makes for flexibility in the train consist.

The total length of the three trailing cars in the four-car train is 231 ft. and 6 in. The total length of the four trailing cars in the five-car train is 295 ft. 6 in. The total height above the rail is 13 ft. and 6 in. The inside width is 9 ft. and 3 1/4 in., which is 3 1/4 inches wider than the inside width of conventional cars, although the outside width is the same.

The trucks, each with four 35-inch wheels, have a wheel base of 8 ft. and 6 in. and are so designed with nickel steel frame construction and hydraulic shock absorbers as to have easy riding qualities at high speed.

The entire car structure is fabricated by the Budd Company's "Shotweld"

process, utilizing stainless steel, having a high tensile, 150 000 lb. per sq. in. This makes the structure radically different from all conventional design; yet the train meets Government and safety requirements. For example, as noticed from the foregoing figures, the weight of the lineal foot of car is only approximately 1 000 lb.

It is the design of this train, with its light weight and low center of gravity, which is largely responsible for its comfortable riding at high train speeds, and its comparatively low operating cost.

The train is equipped with Westinghouse H. S. C. high-speed air brakes, with electric deceleration control, which enables this light-weight train, when travelling at 90 miles per hour, to stop in a shorter distance than conventional trains travelling at 60 miles per hour, which is a very important factor for trains which will operate at times considerably in excess of 100 miles per hour.

The trains are completely air-conditioned for the most adverse weather conditions, using Chrysler « Air Temp » electro-mechanical equipment with Vapor control. The car body is insulated against sound and temperature with 3 inches of efficient material. As much attention was given to insulating the floors as was given to the walls and roof. In this connection double sash with double safety glass is used throughout all these trains which incidently have 51-inch wide windows, which makes for unrestricted view of the landscape. By the use of calcium chloride, frosting and sweating of the windows is prevented.

The trains are exceptionally well illuminated by a general indirect lighting system which gives a very pleasing aspect to the ceiling and interior of the car generally, in addition to which there is provided a local light at each seat which, by means of prismatic lenses, provides each passenger with an illumination of eight foot-candles at the read-

ing plane or position, which, each passenger having control of his own individual light, makes for the utmost in lighting comfort.

The entire train is equipped with the latest type of radio instruments, and installation which makes for clear reception, free from static and undesirable noise under all conditions.

In as much as these trains are all to be operated on fast through, day-light schedules between important cities, no provision has been made for sleeping accommodation; however exceptionally ample, high-grade, commodious and sanitary lavatories and toilets are provided for the use of all passengers. There is also provided ample space for the storage of luggage, with wide, spacious passage-way between the cars for the convenience and safety of the passengers moving from one car to another.

Much attention was given to the design of these trains to insure their riding comfort and freedom from delay en route; also much attention was given to the design of the equipment in order to facilitate maintenance at terminals, this being a very important factor since these trains will have a very high daily mileage, making their time in terminals quite short. For example, Timken roller bearings are used throughout, the installation being such that wheels may be quickly changed.

It has also been necessary to design modern and complete terminal facilities for economically and quickly caring for these trains.

Due to the design of these trains in their entirety and the high daily mileage that they are capable of making, together with the improved modern terminals for inspecting and maintaining, it is estimated that the repairs to the power car including allowance for shopping will be approximately ten cents per mile. The fuel cost with fuel at four cents per gallon will be approximately four cents per mile. The cost of lubrication appro-

ximately and one half cents per mile. In this connection the Rock Island has built a modern crank case drainage oil reclaiming plant at Armordale, Kansas where all internal combustion engine lubricating oil is reclaimed at an exceptionally low cost, the reclaimed oil being equal to if not better than the original lubricant purchased.

It is estimated that in view of the design and high daily mileage that the per mile cost for maintaining the trailing cars will be much less than for maintaining conventional equipment.

It is also estimated that the cost of operating these trains, based on past service and material costs, will not be in excess of 45 cents per mile.

* * *

One railroad is at this time making a study relatively to the possibilities of diesel-electrifying their suburban service, involving some one hundred light-weight 100-passenger capacity steel cars, the trucks of which were designed, when the cars were built, for carrying electric traction motors.

The average length of run is approximately 20 miles and possibly three or four of 65 miles.

All trains operate into a stub track terminal station for incoming and outgoing trains, hence equipment of the multiple-unit type is almost compulsory.

It has therefore been proposed that each car be a power car, with a control station at diagonally opposite end corners of the car with four small (overall dimension), light-weight 1 800 r.p.m. diesel engines developing, when supercharged, 175 H.P. each, or a total of 700 H.P., per car, suspended in a shock and vibration insulated cradle frame under the car. Each engine is direct connected to its individual 600-volts D. C. generator, together with small air compressor and battery charging generator, and individual traction motor except for direction reversing contactors.

In other words each of the four power plants will be self-contained, yet all operated and controlled through a multiple-unit 64-volt cable train line system with equalizing air line for brake system.

The cars will be heated through heat-exchanger by the engine exhaust. The cars will be operated singly or in any length of train desired.

The details have been worked out and surprising as it may seem are quite simple. It had been hoped to have detail drawings available for this report; however, the manufacturers, on account of some patent developments say it will be impossible to release them before the latter part of this year.

In this connection it might not be far wrong to prophesy that this multiple-unit diesel-electric system may be well applicable to other than suburban class rail service, especially so in view of its promised reliability and indicated possibilities of low first cost when utilizing equipment manufactured on a mass production basis. Such design also tends to greater availability for service and comparatively low maintenance costs.

* * *

Several other railroads are at this time figuring on some diesel-electric light-weight streamlined passenger trains, also some of the latest type diesel-electric switchers, the demand for which seems to be steadily increasing, largely due to their demonstrated operating efficiency and comparatively low-operating costs, especially so when they are in twenty-four/hour service. Mention is made of this situation in this report for the reason that the more diesel-electric power plants are placed in railway service the simpler becomes the problem of their advantageous use in rail transport.

III. — OIL-ELECTRIC LOCOMOTIVE AND RAILCAR CONTROL.

Generators and control equipment for use with oil engines on locomotives and railcars should be designed to utilize full engine output over as wide a range of voltage and current as possible within the safe limits of the equipment, and should automatically take care of variations in engine output due to varying engine and fuel conditions without overloading the engine at any time. The ideal equipment would maintain maximum permissible generator current as voltage increases until the point is reached where the generator output equals available engine output times generator efficiency. From this point the current would decrease, as the voltage increases, at such a rate that the generator output (volts times amperes) divided by generator efficiency would remain a constant and would be equal to engine output, until the maximum permissible voltage is reached. With poor fuel or a partially disabled engine, the load should be automatically adjusted to the engine torque available. Figure 1 shows the volt-ampere curve for the ideal equipment which would permit full engine utilization without overloading.

Differential field system.

Unfortunately the ideal cannot be obtained, but a number of systems have been developed that approach it more or less. One of the systems first adopted is

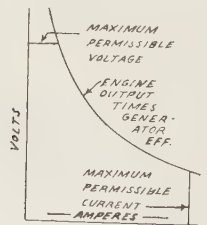


Fig. 1.

one of the simplest and is known as the differential field system. Figure 2 shows the schematic diagram for this system.

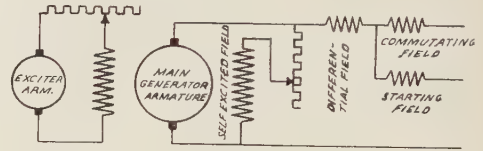


Fig. 2.

The main generator has three field windings exclusive of the starting and commutating fields. The separately excited field is connected across the auxiliary generator armature and is thus maintained at a constant value. The self excited field is connected across the main generator armature and varies with the main generator voltage. The differential field is in series with the main generator armature and opposes the

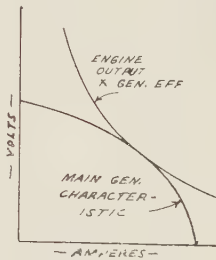


Fig. 3.

other two fields. With low generator output there is not much current in the differential field winding and the field flux is maintained at a high density by the shunt field and the voltage is high. As the load increases, the current through the differential field winding increases, opposes the excitation of the shunt windings and reduces the generator voltage. If these fields are properly designed and adjusted, the main generator will have a volt-ampere curve as shown in figure 3. This curve coincides with the engine curve at only one point and therefore full engine output can be

utilized at only this one point. The system, however, is quite simple and is satisfactory for switching locomotives.

Split pole exciter.

A characteristic more nearly like the ideal may be obtained by placing the differential field winding on a special split pole exciter. Figure 4 shows the schematic diagram and figure 5 the volt-ampere curve for a generator with a split pole exciter.

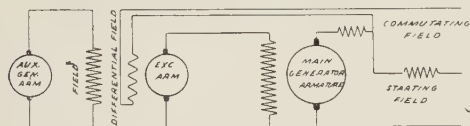


Fig. 4.

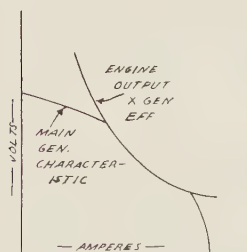


Fig. 5.

The main generator is a shunt wound machine with the field connected across the exciter armature. Figure 6 shows the arrangement of the exciter poles which are in two sections with both sections excited by shunt windings from a

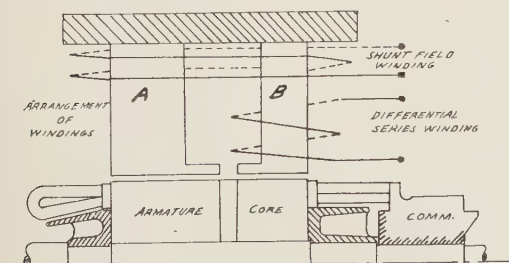


Fig. 6.

constant voltage source, either the auxiliary generator or the battery. The smaller section of each pole is also excited by a series coil carrying main generator current. The flux produced by the series coil opposes that produced by the shunt coil.

When the main generator output is low and the voltage is high, Section B of the exciter pole is saturated by the shunt winding. Due to the saturation of Section B, as the current in the main armature increases, the series winding on Section B opposes the excitation of the shunt winding and after the knee of the saturation curve is reached begins to reduce the generated voltage rapidly with increasing current in the series winding. The effect of this opposing series winding increases up to the point where it completely overcomes the shunt winding and the flux through that portion of the pole Section B becomes zero. At this point of the curve full excitation for the main generator is furnished by Section A of the pole. As the armature current in the main generator further increases, the polarity of Section B reverses. The voltage generated in the armature coils surrounded by the section of the armature core under Section B of the poles then opposes that generated under Section A. The action of the series field continues to reduce the voltage until Section B of the pole again approaches saturation.

The saturation of the smaller section of the pole, first by the shunt winding with the series winding excited at a minimum value, the reversal of the polarity of the pole, and then its saturation in the opposite direction, produces a voltage characteristic of the exciter which, when imposed on the shunt windings of the main generator, causes it to generate a constant kilowatt output over a considerable range of current. The value in kilowatts of the output can be varied by adjustment of field resistances.

On some installations, to overcome the effects of temperature changes in the fields, a thermostat has been embedded in the shunt windings, which operates a small rheostat in the exciter field. The action of the thermostat is to reduce the resistance in the exciter field with temperature increase and thereby counteract the increase in winding resistance. The reverse effect is secured with a drop in temperature. With the use of the split pole exciter and the addition of the thermostat the output of a generator either on a locomotive or car can be held to a very close value.

Metadyne exciter.

For large machines the problem of handling the main generator currents through series windings on the exciter becomes quite difficult and a special exciter known as the metadyne exciter has been developed, the operation of which is briefly as follows :

Notching the poles of a D.C. generator as shown in figure 7 will produce a neutral axis along which the voltage is sufficiently low to permit good commutation. The main brushes $B'B'$ are placed on this axis. Auxiliary brushes $b'b'$ are placed on the neutral axis at right angles to the field flux ff produced by the current in the field winding $f'f'$. With the auxiliary brushes short circuited, a volt-

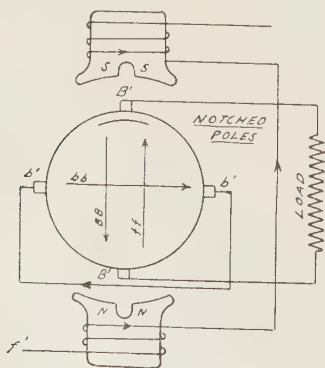


Fig. 7.

age will be generated across main brushes $B'B'$ when the armature is rotated. This voltage is due to the armature conductors cutting the cross field flux bb produced by the current in the short circuited armature. The load current through $B'B'$ will produce a cross field flux BB which is opposed to ff . The current in $b'b'$ is due to the armature conductors cutting a field which is the difference between ff and BB . Consequently a small variation in current through the resultant field flux produces a large variation in the current in the short-circuited armature circuit which in turn produces a large variation in the terminal voltage. Thus the terminal voltage is very responsive to changes in the exciting field current.

The exciting field of the metadyne exciter consists of four sections as shown on figure 8. One section, the variable variator field, is connected across the

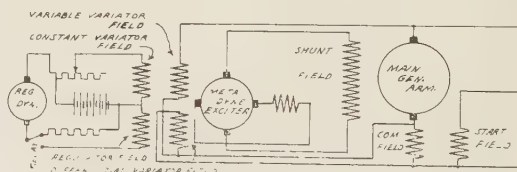


Fig. 8.

armature of the main generator and its excitation varies as the main generator voltage. The constant variator field section is connected in series with a variable resistor, operated by the throttle mechanism, across the battery. Its excitation is constant for any given throttle position. The differential variator field section is connected across the commutating field of the main generator. Its excitation varies with the main generator current and opposes the constant and variable variator fields. The regulator field section is connected in series with the regulator dynamo armature across the battery when the engine is overloaded

and begins to stall. Its excitation increases rapidly with a drop in speed and assists the differential section in lowering the terminal voltage.

The regulator dynamo is a small generator built in a common frame with the metadyne exciter. It operates at low field flux density so as to be very responsive to speed changes.

When the engine is operating at a speed above that at which the regulator dynamo voltage is higher than the battery voltage, the regulator dynamo armature is connected in series with a resistor across the battery. Under this condition the battery is charged at a rate depending on engine speed and the regulator field circuit is open. When the generator load increases to the point where the torque required by the generator exceeds the engine torque, the engine begins to slow down. As the engine slows down, the regulator dynamo voltage decreases, and the battery charging current decreases. When the regulator dynamo voltage drops below battery voltage the current through the armature of the regulator dynamo reverses. This operates a reverse current relay which in turn disconnects the resistor and connects the regulator field in the circuit.

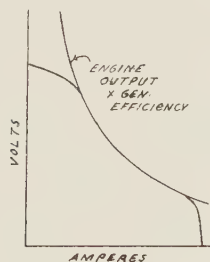


Fig. 9.

As the engine slows down the regulator dynamo voltage decreases and the discharge current from the battery increases. This current passing through the regulator field decreases the exciter voltage which in turn decreases the load

on the main generator until the torque demanded by the generator just equals the available engine torque and the speed becomes constant. Due to the sensitivity of the regulator dynamo a small decrease of engine speed will cause considerable unloading, and consequently the engine speed will not vary a great deal and the load will be limited to available engine output. Figure 9 shows the volt-ampere curve for a generator with the metadyne exciter.

Torque control.

Another method of control that has been in use for some time is known as torque control. This type of control automatically fits the load to the torque available and holds the engine to the selected speed. The engines used with this control must be equipped with variable speed governors, arranged to automatically control the fuel injection to maintain the selected engine speed. Provision must also be made for limiting the amount of fuel that can be injected for each governor setting in order to limit the torque demand to the desired value for each speed. The throttle lever or master controller must have definite notches, each notch providing for a definite governor setting and thus a number of different speeds between idling and full normal speed are provided.

Figure 10 shows the schematic circuit for torque control. The main generator is a shunt wound machine with self and separately excited windings. The self

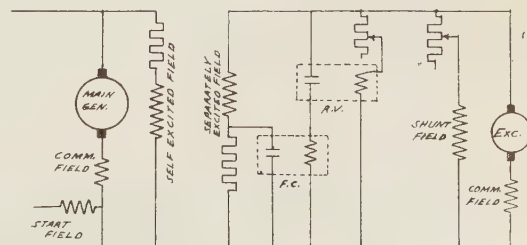


Fig. 10.

excited winding provides excitation proportional to the terminal voltage. The separately excited winding, connected across the exciter armature provides the additional excitation required for correct engine loading. This is controlled by a regulating relay and contactor to provide the necessary variation to maintain definite engine speeds. The regulating relay operates at a fixed current and its operating coil is connected in series with a variable resistor across the exciter armature. The exciter shunt field is also connected in series with a variable resistor across the exciter armature. These variable resistors are controlled by the throttle lever or master controller. For each throttle position a definite engine speed is selected and the proper resistances placed in series with the relay coil and exciter field so that the selected engine speed must be reached before sufficient current will pass through the relay to operate it.

If the load on the engine is light for the speed selected, the speed will increase to the point where the current through the relay coil is sufficient to close its contacts, causing the field contact to close, increasing main generator excitation and terminal voltage. This results in an increased load and the engine slows down until the current through the relay drops below the value at which the relay holds in and the relay drops out. This causes the contactor to drop out, decreasing the main generator excitation and voltage and dropping part of the load. With the equipment properly adjusted the relay vibrates and maintains the engine speed at the selected value and produces a volt-ampere characteristic as shown in figure 11.

Auxiliaries.

With all the methods of control it is necessary to make provision for the operation of auxiliary equipment such as air compressors, radiator fans, motor

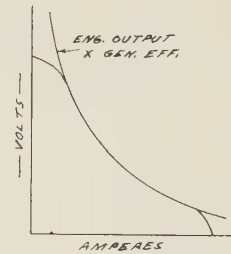


Fig. 11.

blower fans, battery chargers, fuel and lubricating oil priming pumps etc.

With the differential field control a constant potential auxiliary generator of sufficient capacity to handle all auxiliaries is usually used, mounted on a shaft extension on the main generator.

With the split pole exciter, a constant potential auxiliary generator is usually used to take care of the auxiliary load. This may be direct connected or belted to the main generator or driven by an auxiliary engine.

With the metadyne exciter, a constant potential auxiliary generator mounted on the main generator shaft extension takes care of the auxiliaries and the metadyne exciter is belt driven from the end of the auxiliary generator shaft.

With torque control, the most common practice is to provide for switching the auxiliaries back and forth between the main generator and the auxiliary generator. The main generator carries the auxiliary load while the engine is idling and the auxiliary generator carries the load at higher speeds. In some instances a small control generator is used to measure engine speed and a constant potential auxiliary generator is used to carry all the auxiliary load at all times.

With any of the control schemes the auxiliaries may be direct connected to or belt driven from the main generator sets.

IV. — THE PROBLEM OF BRAKING.

The problem of braking the high-speed train running at times as rapidly

as 120 miles per hour is a most difficult one, in fact seems to be the most difficult of all the problems involved.

The wheel at high speed has a job meeting its load requirements without being outraged more or less by high, long-continued brake shoe pressures; magnetic track brakes, have a low efficiency at high-speeds; brake drums and regenerative braking also have their drawbacks.

In the small fully articulated diesel-electric train with no slack between the component cars and comparatively well balanced wheel loads throughout the train, the braking problem has not been as difficult as it is in the case of non-articulated trains with heavy power cars or locomotive units.

However the development of the electrical control by means of which the application and release of all brakes are simultaneously effected on all cars regardless of the length of the train, together with the development of a device for automatically reducing the shoe pressure as the speed decreases, has done much to simplify the problem and it is not too much to hope that the metallurgists and wheel manufacturers will be able to greatly improve their wheels so as to withstand the strains imposed upon them. In any event it is felt that the electro-pneumatic brake will meet all the requirements and demands made upon it, also the wheel.

V. — RAIL MOTOR CARS IN THE UNITED STATES.

In the United States we have classified our automotive equipment as motor cars and motor car trains, — power cars and power car trains, — and switchers; sometimes power cars and switchers are called locomotives.

We have one class or type of motor cars and motor car trains utilizing internal combustion engines, gasoline or diesel, in more or less conventional cars

of typical American design except that they are usually somewhat lighter than cars used in steam trains.

Then we have the high-speed lightweight, streamlined trains in which the power units are generally called power cars although they are sometimes called locomotives.

And then we have the switcher type, sometimes called a locomotive and used for switching and light freight train service, etc.

Until recently gasoline engines have been largely used in motor cars and small switchers, diesels in high-speed trains and large switchers or locomotives. Today, however, practically all are diesels and all with electric transmissions.

The more or less conventional design of cars operate in comparatively slow passenger service : 50 to 400 miles per day. The smaller of the light-weight streamlined high-speed trains in fast through passenger service cover from 300 to a maximum of 800 miles per day, while the long-distance heavier train operates as many as 2 500 miles in continuous run.

Generally speaking, the higher the mileage made, the lower the operating costs.

The utilization factor or availability of all types is usually considerably better than 95 %.

Light repairs are usually necessary after 125 000 miles; a heavier class including traction motor banding and such at 250 000 miles; another light repair at 375 000 miles; a general repair at 500 000 miles; however, it is possible that the general repair mileage can be considerably extended.

The average 250-H.P. to 500-H.P. conventional motor trains operate at a total overall cost of approximately 30 to 40 cents per mile; the 500 to 800-H.P. at 40 to 60 cents per mile (daily mileage comparatively low).

Diesel-electric, gas-electric and other internal-com

Purchaser.	Number.	Wheel arrange- ment.	Service.	Type
Aluminium Co. of America	1	...	...	Diesel-
Atchison, Topeka & Santa Fe	1	B-B	Sw.	Diesel-
Baltimore & Ohio	2	C-C	Pass.	Diesel-
	1	B-B	Sw.	Diesel-
Bessemer & Lake Erie	1	B-B	Sw.	Diesel-
Birmingham Southern	5	B-B	Sw.	Diesel-
	5	B-B	Sw.	Diesel-
Boston & Maine	3	B-B	Sw.	Diesel-
Chicago, Burlington & Quincy	2**	B-B	Pass.	Diesel-
	2	B-B	Pass.	Diesel-
Chicago Great Western	1	B-B	Sw.	Diesel-
	2	B-B	Sw.	Diesel-
	3	B-B	Sw.	Diesel-
Chicago, Rock Island & Pacific	6	B-B	Pass.	Diesel-
Great Lakes Steel Co.	3	B-B	Sw.	Diesel-
Gulf Refining	1	B-B	Sw.	Diesel-
Joplin-Pittsburgh	1	B-B	Sw.	Propane-
La Salle & Bureau County	1	B-B	Sw.	Gas-el
Milwaukee Coke & Gas Co.	1	B-B	Sw.	Diesel-
Monongahela Connecting	1	B-B	Sw.	Diesel-
	1	B-B	Sw.	Diesel-
New York Central	7	B-B	Sw.	Diesel-
New York, New Haven & Hartford	5	B-B	...	Diesel-
	5	B-B	...	Diesel-
Portland Terminal	3	B-B	Sw.	Diesel-
Union Pacific	1	...	...	Diesel-
	1	...	...	Gasoli
Union Pac.—So. Pac.—C. & N. W.	1*	...	Pass.	Diesel-
Union Pacific-C. & N. W.	1*	...	Pass.	Diesel-
Universal Atlas Cement	1	B-B	Sw.	Diesel-
U. S. Army	2	B	Sw.	Gas-el
Westinghouse Elec. & Mfg. Co.	3	B-B	Sw.	Diesel-
Wichita Valley	1	B-B	Fr't. & Sw.	Diesel-

** Each of two units.

* Each of three units.

1936.

motives for service in the United States.

Weight. (lb).	Horse- power.	Date of order.	Date of delivery.	Builder.
...	600	November 1936.	1937.	American.
4 700	600	January 1936.	July 1936.	Electro-Motive.
10 000	3 600	July 1936.	Feb.-Mar. 1937.	Electro-Motive.
00 000	600	November 1936.	December 1936.	Electro-Motive.
13 500	530	April 1936.	July 1936.	Westinghouse.
30 000	900	October 1936.	Jan. 1937.	West—American.
50 000	900	September 1936.	Jan. 1937.	West—Electro-M.
00 000	600	June 1936.	July 1936.	Electro-Motive.
27 940	3 000	Nov.-Dec. 1935	Oct.-Dec. 1936.	G. E.—Electro-Motive.
21 260	1 800	Dec. 1935.	October 1936.	G. E.—Electro-Motive.
26 000	800	January 1936.	January 1936.	Westinghouse.
28 000	800	April 1936.	Apr.-May 1936.	Westinghouse.
00 000	600	June 1936.	August 1936.	G. E.—Electro-Motive.
10 000	1 200	November 1936.	June 1937.	G. E.—Electro-Motive.
40 000	530	January 1936.	...	West.—Baldwin.
90 000	290	September 1936.	...	West. Por.-Her.
30 000	500	February 1936.	October 1936.	West. Ply-Climax.
44 000	500	February 1936.	August 1936.	West. Ply-Climax.
20 000	400	September 1936.	December 1936.	G. E. Inger.-Rand.
59 000	550	January 1936.	June 1936.	G. E. Cooper-Bess.
18 000	1 000	October 1936.	Feb. 1937.	G. E. Cooper-Bess.
02 000	600	April 1936.	July 1936.	G. E. Electro-Motive.
99 000	600	Dec. 1935.	Sept.-Nov. 1936.	G. E. Ing.-Rand.
99 000	660	Dec. 1935.	Sept.-Nov. 1936.	G. E. Cooper-Bess.
00 000	600	June 1936.	July 1936.	American.
...	3 600	July 1936.	...	Electro-Motive.
...	...	July 1936.	...	Baldwin.
...	5 400	December 1936.	...	Electro-Motive.
...	5 400	December 1936.	...	Electro-Motive.
00 000	600	September 1936.	December 1936.	G. E. American.
60 000	225	April 1936.	.....	West. Atlas Le Roi.
50 000	530	August 1936.	December 1936.	West. Baldwin.
70 000	900	January 1936.	December 1936.	Cummins G. E. Traction.

The 600 to 1 200-H.P. light-weight streamlined trains at 30 cents to 50 cents per mile; the 1 500 to 5 000-H.P. trains, estimated at from 60 cents to \$ 1.60 per mile (daily mileage very high), much depending on the type of design, the ability of the operating and maintenance forces, the class of equipment and the mileage made; hence any figures given are only approximate.

Today steam trains must act as reserve for the diesel electric high-speed trains to the best of their ability; eventually it is possible there may be enough of the new type equipment to provide the necessary reserve stock.

The railway companies do not as a rule put out their net earnings on these trains; however, it is generally understood that allowing 15 % for depreciation and obsolescence, all of these modern trains are paying a handsome return on the investment.

Sixty-five mile per hour schedule speed seems to be the desired mark and if all necessary precautions are taken seems to be not unreasonable even for very long distances. Ten minutes clearance is usually required for these trains.

The usual financial arrangements are made for paying off but with much greater attention being given to the factors of obsolescence and depreciation.

The cost of one of these ultra-modern light-weight high-speed semi-articulated trains ranges from approximately \$ 250 000.00 for the smaller three and

four-car trains, and up to \$ 1 500 000.00 for a seventeen-car train.

Most of the trains are heated by steam produced in an automatic steam boiler, oil fired, with electric control. On a few, the condensate from the heating coils is returned by pump, but on most is wasted.

One road is figuring on electric heating from auxiliary diesel-electric power plants and another road is figuring on using under each car a 30 to 50-H.P. diesel engine driving an electric generator to furnish electric current to heaters in the car and for electric lighting, fan motors, etc., — also for driving air conditioning compressor, the engine exhaust through a heat exchanger for heating the car, co-ordinated with the electric heating and all working out to a fair heat balance on the diesel fuel.

It is impossible at this time to definitely recommend a heating system; however, it is felt that in the near future some definite findings will be made.

All indications point to much extended use of these new types of trains as evidenced by recent orders of the Union Pacific, Southern Pacific, Chicago and North Western, Burlington, Rock Island, and others.

Recently in the United States, some of the Western and Southern railways received permission from the Interstate Commerce Commission to experiment with some new passenger travel rates — notably.

Round trip in coaches	1.8 cents per mile.
One way in coaches	2 »
Round trip in parlor and sleeping cars . . .	2 »
One way in parlor and sleeping cars . . .	3 »

These rates proved so successful in building up passenger travel that they were duly authorized by the Commission to continue them in effect. However, due to the tremendous development of all-weather hard surface highways through-

out the U.S.A. and low cost automobiles which have a comparatively low operating cost, it is possible for an automobile owner to carry several with him when travelling, which largely reduces the cost per mile per passenger so carried.

As a result of this situation the railways are finding it impossible to regain much of their short-haul or local passenger business, also some of their long-haul business.

To combat the situation some of the railways are making a study relatively to the possibility of establishing a very low cost zone rate on the basis of better utilization of the trains operated — for example : between Kansas City and Chicago, or between any two intermediate points between Kansas City and Chicago, or between any intermediate point and either Chicago or Kansas City, that a flat zone rate would be charged — say possibly of \$ 2.00.

If such a plan could be worked out it is felt that it would do much to, by reason of the low and economic cost, throw a tremendous passenger traffic back to the rail.

* * *

In closing it might not be amiss to call attention to the trend toward faster and better passenger trains in the United States and yet at the same time put in effect comparatively lower travel rates, which necessitates a reduction in operating and maintenance costs.

Such a practice is, of course, always a good one in any business in any country : — « Improvement and betterment of that which you have to sell, your

patrons at the same time reducing the price they have to pay », provided the management through the efforts of its staff and force is able to reduce the cost of production to the point that a good and sufficient margin is left for the essential profit.

The trend of wages is usually toward the higher levels so we are left with two major opportunities for reducing the cost of operating and maintaining these fine trains :

(1) By so designing them that the tare weight is very low and yet the equipment rugged, reliable, and safe — recent demonstrations have proved that this can be done; by so designing the diesel engines, transmissions and controls together with all their accessories that they too are light in weight and yet rugged and reliable.

(2) By the greatest possible utilization; the greater the daily mileage, the greater the revenue and the lower the fixed operating and maintenance charges.

In this connection it must be remembered that suitable modern facilities for maintenance are exceedingly essential and that just as essential is a strong, carefully educated and trained personnel, closely and well supervised, all of which is entirely feasible if those in authority insist that the modernization be complete in every detail and nothing left wanting.

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

13th SESSION (PARIS, 1937).

QUESTION V.

Recent improvements in steam locomotives

of the usual type and tests of new designs (high-pressure reciprocating locomotives and turbine locomotives) as regards construction, quality of materials used, efficiency, working conditions, maintenance and financial results.

Testing locomotives

at locomotive experimental stations, and in service with dynamometer cars and brake locomotives.

REPORT

(Germany, Austria, Belgium and Colony, Denmark, Finland, France and Colonies, Hungary, Luxemburg, Norway, Netherlands and Colonies, Poland, Sweden and Switzerland),

by A. PARMANTIER,

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Ingénieur en Chef du Service des Machines, Paris-Orléans-Midi Railways.

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<i>Germany :</i>	(b) <i>Algeria and Tunisia :</i>
Deutsche Reichsbahn.	Algerian Railways ⁽²⁾ .
<i>Austria :</i>	(c) <i>Colonies and Protectorates :</i>
Federal Railways.	(α) <i>Africa :</i>
<i>Belgium :</i>	Colonial Railways in French West Africa :
Belgian National Railways Company.	Abidjan-Niger Railway.
<i>Finland :</i>	Réunion Island Railway.
State Railways.	(β) <i>Asia :</i>
<i>France, Algeria, Tunisia, Colonies</i>	Damas-Hamah Railway and Extensions.
<i>and Protectorates :</i>	<i>Hungary :</i>
(a) <i>France :</i>	Royal State Railways.
Alsace-Lorraine Railways.	<i>Netherlands :</i>
Est Railways.	Netherlands Railways.
State Railways.	<i>Poland :</i>
Nord Railway.	State Railways.
Paris-Lyon-Méditerranée (P. L. M.) Rail-	<i>Sweden :</i>
ways.	Grängesberg-Oxelösund Railways Com-
Paris-Orléans—Midi Railways ⁽¹⁾ .	<i>Switzerland :</i>
	Federal Railways.

Foreword.

The development of the steam locomotive of the classic type which was already noticeable by 1930, the date of the Madrid Congress, has continued at an accelerated rate. Most of the railways have profited from the information obtained from running tests and tests on the test plant and have altered their locomotives more or less profoundly, increasing their power and their efficiency very considerably.

It has not been possible to show separately the effect of each improvement on the efficiency. Usually the Railways carry out at one and the same time a whole series of modifications, so that the share of each alteration in the overall result cannot be determined.

In addition each partial result depends upon the initial state. We considered, therefore, that the best thing to do was to

reproduce the power and efficiency figures corresponding to the last stage of development of the locomotives.

Looking at the question from another angle, we wished to bring out the effect on repairs of each improvement, as no improvement is of any value if it does not result in an actual reduction in operating costs, or an increase in the receipts.

The Railways have unfortunately not been able to draw up the financial balance sheets they were asked to send.

We have also had to give up any idea of making a comparison between the maintenance costs of modern locomotives, as these engines as a rule have been in traffic too short a time for the result of a complete maintenance cycle to be available.

* * *

(1) Joint operation of the *Paris-Orléans* and *Midi* Railway Systems.

(2) Joint management of the *Algerian State Railways* and the *Algerian Lines* of the *Paris-Lyon-Méditerranée* Company.

PART ONE.

Steam locomotives of the usual type.

CHAPTER I.

Increased boiler pressure.**I. — Boiler pressures generally adopted on new or rebuilt superheated locomotives.**

Table I, which gives the leading dimensions of the engines built or rebuilt since 1930, shows an almost general tendency for the pressures in boilers of usual types to be increased; pressures of 18 and 20 kgr./cm.² (256 and 284 lb. per sq. in.) are in use, not only on compound, but also on simple-expansion locomotives, and a pressure of 25 kgr./cm.² (356 lb. per sq. in.) has been tested on compound engines.

The principal characteristics of boilers with 18 kgr./cm.² pressure and over are given in Table II.

II. — Pressures adopted by the Administrations.

The *Deutsche Reichsbahn* has adopted the pressure of 16 kgr./cm.² (228 lb. per sq. in.) for simple-expansion locomotives of the standard type, and 14 kgr./cm.² (199 lb. per sq. in.) for less powerful engines, and has also built, as an experiment, three types of locomotives with 25 kgr./cm.² (356 lb. per sq. in.) and 4 types of compound locomotives with 20 kgr./cm.² (284 lb. per sq. in.) pressure.

The *Austrian Federal Rys.*, which have only built simple expansion engines, have limited the boiler pressure to 13 kgr./cm.² (185 lb. per sq. in.) on their 4-6-4 locomotives, and 16 kgr./cm.² (228 lb. per sq. in.) on their light 4-8-4 locomotives.

The *Belgian National Rys. Co.* has put into service Class 1, 4-6-2 locomotives,

with 4 simple-expansion cylinders and a boiler pressure of 18 kgr./cm.² (256 lb. per sq. in.)

The *Alsace-Lorraine Rys.* have raised the pressure of their 4-6-2 locomotives from 16 to 17 kgr./cm.² (from 228 to 242 lb. per sq. in.), without altering the boilers, and have built two new type 4-6-2 engines with two simple-expansion cylinders, and 20 kgr./cm.² (284 lb. per sq. in.) boiler pressure, and two of the 2-10-2 type with 3 simple-expansion cylinders and the same boiler pressure of 20 kgr./cm.².

The *Est Railways* use 14 kgr./cm.² (199 lb. per sq. in.) for their simple-expansion locomotives, and 17 to 20 kgr./cm.² (242 to 284 lb. per sq. in.) for their compounds; when altering certain of their 4-6-2 and 4-6-0 locomotives, they raised the pressure from 16 to 17 kgr./cm.² (228 to 242 lb. per sq. in.) and from 16 to 18 kgr./cm.² (228 to 256 lb. per sq. in.) respectively; in the latter case the pressure of 20 kgr./cm.² (284 lb. per sq. in.), first of all considered, has been abandoned, owing to deformation of the barrel-ring on which the dome is fitted, under the pressure of 30 kgr./cm.² (427 lb. per sq. in.).

The *French State Rys.* have adopted a pressure of 14 kgr./cm.² (199 lb. per sq. in.) for their simple-expansion locomotives, and 20 kgr./cm.² (284 lb. per sq. in.) for their 4-8-2 compound locomotives. The first of the 4-8-2 locomotives, N° 241.101, has, however been given a 20 kgr./cm.² boiler pressure, although this is a simple-expansion engine.

The *Nord Railway* uses 17 and 18 kgr./cm.² (242 and 256 lb. per sq. in.) pressures on its 4-6-2 locomotives and 2-10-2 compound locomotives, and 18 kgr./cm.² on its 2-8-2 simple-expansion suburban tank engines.

The *Paris-Lyon-Méditerranée (P.L.M.)* Railways have retained the pressure of

TABLE I.

Leading characteristics of recently built or altered locomotives.

ADMINISTRATIONS.	Sequence number.	Class of locomotives.	Number of loco- motives.	Date built (B) or altered (A).	Types of locomotives.	Characteristics of the boiler.										Characteristics of motion.										Weight in working order.		Remarks.
						Pressure (kg./cm ²)	Grate area (m ²)	Heating surface.			Super- heating surface (m ²)	Length of tubes (m.)	Kind		Special devices in firebox.	Simple expan- sion (S.E.) or com- pound (C).	Cylinders.				Type of valve gear.		Diameter of driving wheels (m.).	Type of fast pipe.	Adhesive weight (tons).	Total weight (tons).		
								Firebox (m ²)	Tubes (m ²)	Total (m ²)			of firebox.	of com- bustion chamber.			HP.		LP.		HP.	LP.						
																	Number of cylinders.	Diameter (m.).	Number of cylinders.	Diameter (m.).							Piston stroke (m.).	
German Reichsbahn	1	03	...	1930 (B)	4-6-2	16	4.05	...	...	202	70	6.800	Steel.	...	...	S.E.	2	0.600	...	...	0.660	Hensinger-Walschaerts.	...	2.600	Ordinary.	53.4	99.6	...
	2	021-04	2	1931 (B)	4-6-2	25	4.10	20	180.8	206.8	84.6	6.800	IZI steel.	...	...	C	2	0.350	2	0.520	0.660	Hensinger-Walschaerts conjugated; piston valves, double ported valves.	...	2.000	Ordinary.	...	109.5	...
	3	71	4	1934 (A)	2-4-2 T	20	1.37	...	...	67.4	28.6	3.500	Molybdenum steel.	...	...	S.E.	2	0.310	...	...	0.660	Hensinger-Walschaerts.	...	1.500	...	50	59	...
	4	17 ²	2	1934 (A)	4-6-0	25	2.85	14.8	137.76	152.65	76.41	4.900	Nickel steel.	...	...	C	1	0.400	2	0.500	0.630	Hensinger-Walschaerts.	...	1.980	...	53.9	84.7	...
	5	05	2	1935 (B)	4-6-4	20	4.70	18.6	237.4	256	90	7.000	Copper.	...	...	S.E.	3	0.450	...	...	0.660	Hensinger-Walschaerts.	...	2.300	...	53.3	126.7	Standardized, « Knorr » feed heater.
	6	61	1	1935 (B)	4-6-4 T	20	2.75	14	137.9	151.9	69.2	5.000	Copper.	...	...	S.E.	2	0.460	...	...	0.750	Hensinger-Walschaerts.	...	2.300	...	53.6	128.3	Do.
	7	84	2	1936	2-10-2 T	20	3.76	14.9	192	210.10	85	4.700	Molybdenum steel.	...	...	S.E.	3	0.480	...	...	0.660	Hensinger-Walschaerts.	...	1.460	...	52.5	127.5	...
	8	44	...	1933	2-10-0	25	4.70	...	...	220.4	109.7	5.800	Nickel steel.	...	Siphon.	C	2	0.420	2	0.680	0.660	Hensinger-Walschaerts conjugated; piston valves.	...	1.400	Ordinary.	100.7	115.3	« Knorr » feed heater.
	9	114	1	1929 (B)	2-8-4	15	4.72	...	...	262	77.8	6.000	Copper.	...	...	S.E.	3	0.530	...	...	0.720	Lentz-Marshall with oscillating cams.	...	1.900	Ordinary.	72	118.7	DABEG » feed heater.
Austrian Federal Rys.	10	214	7	1928 (B)	2-8-4	15	4.72	...	...	262	77.8	6.000	Do.	...	...	S.E.	2	0.650	...	...	0.720	Lentz with oscillating cams.	...	1.900	Kylala.	72	118	Feed water heater.
	11	729	10	1935 (B)	4-6-4	13	3.55	...	...	171.3	41.1	4.900	Do.	...	...	S.E.	2	0.500	...	...	0.720	Lentz.	...	1.574	Filip.	47.3	106.8	« Heintl » feed heater.
	12	D.T.1	10	1935 (B)	2-4-2	16	0.83	...	...	42.48	16.47	3.265	Do.	...	...	S.E.	2	0.290	...	...	0.570	Lentz.	...	1.450	...	26	45.5	Auxiliary oil firing « feed » heater.
Belgian National R. Co.	13	5	4	1930 (B)	2-8-2	14	5.5	22.19	262.09	284.28	112.52	6.000	Do.	...	4 arch tubes.	S.E.	2	0.720	...	...	0.720	Walschaerts.	...	1.700	...	90.8	130.5	« Superior » feed heater.
	14	35	4	1930 (B)	2-8-0	14	5.07	20.07	193.59	214.66	91	4.500	Do.	...	...	S.E.	2	0.650	...	...	0.720	Walschaerts.	...	1.450	...	93.2	108.4	...
	15	1	15	1935 (B)	4-6-2	18	5	17.32	217.48	234.8	112	6.000	Do.	...	...	S.E.	4	0.420	...	...	0.720	Walschaerts conjugated; double ported valves.	...	1.980	Kylechap (double) or Lemaitre.	72	126	...
French State	16	7	5	1935 (B)	4-6-0	16	3.08	...	...	168	68.5	4.400	Do.	...	...	C	2	0.400	2	0.600	0.640	Walschaerts.	...	...	...	...	...	...
	17	P ¹	2	1935 (B)	4-6-2	15	3.54	...	...	195.4	68	6.000	Do.	...	...	S.E.	...	...	...	...	...	Walschaerts.	...	...	...	...	...	...
French Est.	18	S. 14	60	1931-36 (B)	4-6-2	17	4.27	...	...	211.97	63.5	5.900	Copper and steel.	...	...	C	2	...	2	...	...	Walschaerts.	Trick or Dabeg valves.	...	Kylechap or improved clover-leaf.	...	...	...
	19	S. 16	2	1933 (B)	4-6-2	20	4.5	...	...	223.7	73.8	5.905	Copper.	...	...	S.E.	2	0.575 or 0.540	...	...	0.720	Caprotti.	...	1.950	Kylechap (double)	60	107.4	...
	20	G. 16	2	1936 (B)	2-10-2	20	5	25.12	220.07	245.19	101.47	5.905	Steel.	Steel.	...	S.E.	3	0.575	...	...	0.720	Caprotti.	...	1.500	Kylechap (double variable).	100	...	...
	21	141.703 to 742	40	1930-31 (B)	2-8-2 T	16/14	2.80	17.30	122.33	139.63	35.98	4.300	Copper.	...	Arch tubes	S.E.	3	0.510	...	...	0.660	Walschaerts.	...	1.420	...	74.6	...	...
	22	150.141 to 195	55	1930-31 (B)	2-10-0	14	3.25	...	...	203.26	81.14 and 61.46	5.000	Do.	...	Arch tubes	S.E.	3	0.560	...	...	0.660	Walschaerts.	...	1.000	...	...	...	...
	23	241.002 to 041	40	1931 (B)	4-8-2	20	4.43	...	...	223.20	94.20 and 69.94	6.000	Do.	Copper.	Arch tubes	C	2	0.425	2	0.660	0.720	Walschaerts.	Walschaerts; double ported valves.	1.000	Ordinary (standardized)	...	...	...
	24	230.103 to 280	178	1935-36 (A)	4-6-0	18	3.16	...	...	135.48	34.76	4.400	Do.	...	Arch tubes	C	2	0.370	2	0.590	0.680	Walschaerts.	Do.	1.000	...	...	82.48	...
	25	231.001 to 040	40	1935-36 (A)	4-6-2	17	4.27	...	...	211.68	68.64 and 54	5.900	Do.	...	Arch tubes	C	2	0.420	2	0.640	0.650	Walschaerts.	Do.	1.000	Ordinary (standardized)	...	100.44	...
	26	231.051 to 073	23	1935 (A)	4-6-2	17	4.33	17.71	178.37	196.08	80	5.900	Steel.	...	Siphon.	C	2	0.420	2	...	0.650	Dabeg O.C. with oscillating cams.	...	1.501	Ordinary (standardized)	...	100.248	...

TABLE I. (Continued.)

TABLE II.

Characteristics of boilers having a pressure of 18 kgr./cm² (256 lb. per sq. in.) and over.

ADMINISTRATIONS.	Class of locomotives.	Types.	Number of locomotives.	Year built (B) or altered (A).	Boiler pressure. <i>kgr./cm².</i>	Grate area <i>m².</i>	Heating surface <i>m².</i>	Super-heating surface <i>m².</i>	Type of firebox and staying.	Materials and characteristics.				Weight of boiler		REMARKS.
										Firebox.	Combustion chamber.	Barrel.	Smoke-box.	total, empty. <i>(metr. t.).</i>	kgr. per <i>m²</i> of heating surface	
GERMANY.																
<i>Deutsche Reichsbahn</i>	021-04	4-6-2	2	1931 (B)	25	4.1	206.8	84.6	...	Chrome-molybdenum steel.	...	Chrome-molybdenum steel.	...	32.900	189.5	
		2-4-2 (tank)	4	1934 (A)	20	1.37	67.4	28.6	...	Molybdenum steel.	...	Molybdenum steel.	...	11.600	172.1	
	17 ²	4-6-0	2	1934 (A)	25	2.85	152.65	76.41	...	Special steel.	...	Special steel.	...	25.200	165	
	05	4-6-4	2	1935 (B)	20	4.70	256.0	90	...	Tens. = 48.55 kgr./mm ² . Molybdenum steel.	...	Tens. = 48.55 kgr./mm ² . Molybdenum steel.	Steel.	...		
	61	4-6-4 (tank)	1	1935 (B)	20	2.75	151.9	69.2	...	Do.	...	Do.	...	22.400	147.4	
	84	2-10-2 (tank)	2	1936	20	3.76	210.10	85	...	K. 47 molybdenum steel.	...	Do.	...			
	44	2-10-0	...	1933	25	4.70	220.4	109.7	...	Nickel steel.	...	Nickel steel.	...	...		
BELGIUM.																
<i>Belgian National Rys. Co.</i>	1	4-6-2	15	1935 (B)	18	5	235	112	Flamme. Vertical and cross stays.	Copper; Tens. = 22 kgr./mm ² . E = 37 %. Copper stays.	...	Steel with 2-2.3 % nickel. Tens. = 52 kgr./mm ² . E = 23 %.	Steel; tens. 35 kgr./mm ² ; E = 20 %.	37.500		
FRANCE.																
<i>Alsace-Lorraine Rys.</i>	S.16	4-6-2	2	1933 (B)	20	4.50	223.70	73.80	Wide. Flexible and closed stays.	Red copper. Stone's bronze or manganese copper stays.	...	(1) Steel with 2 to 3 % nickel. Tens. = 45 kgr./mm ² ; E = 25 %.	Copper steel.	31.826 (b)	142.2 (b)	(a) Loc. No. 1401 (c) Loc. No. 1402 (b) EXcluding brass work.
	G.16	2-10-2	2	1936 (B)	20	5	245.19	101.47	Wide. Flexible stays.	Steel. Mild steel stays. Copper. STU No. 86. nickel-copper stays.	Steel.	(2) Chrome-copper steel; tens = 50.5 kgr./mm ² ; E = 20 %. STU-B steel and nickel steel.	Do.	40.700 (b)	166.2 (b)	Do.
<i>Est Rys.</i>	241.002-041	4-8-2	40	1931 (B)	20	4.43	223.20	94.20	Belpaire.	Do.	Copper.	STU-B steel.	STU-A steel.	38.850 (c)	174 (c)	(c) Boiler complete with brass work, superheater, regulator and lagging.
	230.103-280	4-6-0	178	1935-36 (A)	18	3.16	135.48	34.76	Belpaire.	Do.	Copper.	Do.	Do.	25.460 (c)	188 (c)	Do.
<i>State Rys.</i>	241.001-039	4-8-2	39	1931-32 (B)	20/18	4.43	223.20	94.20	Belpaire. Wide firebox	STU copper. Manganese copper stays.	STU copper	Do.	Do.	31.105 (a)	134.80 (a)	(a) Fittings excluded.
	241.040-050	4-8-2	10	1933-34 (B)	20	5	268.35	85.65	Round saddle, wide firebox, direct stayed.	Do.	Do.	Front and back courses and straps, special nickel steel.	Do.	32.510 (a)	121.20 (a)	Do.
	241.101	4-8-2	1	1932 (B)	20	5	268.35	85.65	Round saddle, wide firebox, direct stayed.	Do.	Do.	Front and back courses and straps, special nickel steel.	Do.	32.510 (a)	121.20 (a)	Do.
<i>Nord Ry.</i>	4.1201.1272	2-8-2	72	1932-35 (B)	18	3.087	203.33	64.25	Belpaire.	Copper.	...	Boiler steel.	Boiler steel.	23.000	112.5	
	5.1201.1230	2-10-0	30	1933-35 (B)	18	3.48	195.98	61.01	Belpaire.	Do.	...	Do.	Do.	26.000	132.5	
<i>P.L.M. Rys.</i>	241.C.1	4-8-2	1	1930 (B)	20	5.006	248	91.30	Crampton outer firebox — wide inner firebox, radial stays.	STU copper. Manganese copper stays.	Copper.	Back course : STU-B steel. Middle and front courses : 3 % nickel steel. Tens. = 50 kgr./mm ² . E = 20 %.	STU-B steel.	27.700 (d)	113.6 (d)	(d) Bare boiler with tubes but no other fittings (grate, ashpan, regulator, superheater, etc.); bare smoke box.
	151.A 1 to 10	2-10-2	10	1932 (B)	20	5	243.77	91.64	Do.	STU copper. Manganese copper stays.	Do.	Do.	Do.	27.700 (d)	113.6 (d)	Do.
	231.H-141	4-6-2	1	1933 (A)	20	4.25	203.82	44.58	Crampton outer firebox, wide inner firebox; radial and flexible stays.	Do.	...	...	Do.	21.700 (d)	106.5 (d)	Do.
<i>P.O.-Midi Rys.</i>	240-701	4-8-2	1	1932 (A)	20	3.76	215.90	60.60	Belpaire.	A steel. Stays of AK mild steel, manganese copper or Monel metal.	...	STU-B steel.	Do.	...	...	...
	240.702 to 712	4-8-2	11	1934 (A)	20	3.76	212.77	67.02	Belpaire.	...	...	...	...	...	...	...
<i>Algerian Rys.</i>	231.132 BT	Garratt	12	1936 (B)	20	5.40	259.60	90.60	Belpaire.	Copper.	...	2-2.5 % nickel steel.	2—2.5 % nickel steel.			

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16 kgr./cm.² (228 lb. per sq. in.) on their recent 4-6-2 and 4-8-2 compound engines; they have raised the pressure of one 4-6-2 locomotive, N° 231.H-141, to 20 kgr./cm.² (284 lb. per sq. in.) and built ten 2-10-2 and one 4-8-2 (locomotive N° 241.C-1) with this same pressure. On the 231.H-141 locomotive, the original firebox has been retained with larger diameter stays and crown stays, and barrel plates increased to 23 mm. (29/32") thickness.

The *P.O.-Midi Railways* have raised the boiler pressure of their 4-6-2, 231.700 class, locomotives from 16 to 17 kgr./cm.² (228 to 242 lb. per sq. in.), without any appreciable alteration of the boiler dimensions; on the other hand when rebuilding their 4-6-2 locomotives Nos 501 to 589, as 4-8-0 engines, the increase in pressure from 16 to 20 kgr./cm.² (228 to 284 lb. per sq. in.) meant using barrel plates 22 mm. (7/8") thick, assembled with three rows of rivets, and with slightly stronger staying and firebox tube plate [15 mm. (19/32")].

The *Algerian Railways*, after having put into service, in 1932, a « Garratt » locomotive of the 4-6-2—2-6-4 type, with 4 simple-expansion cylinders, and a boiler pressure of 16 kgr./cm.² (228 lb. per sq. in.), has now under construction 10 locomotives of the same type with a boiler pressure of 20 kgr./cm.² (284 lb. per sq. in.).

The *Polish State Rys.* have only built in recent years simple-expansion locomotives and have limited the pressure to 15 kgr./cm.² (213 lb. per sq. in.).

A pressure of 20 kgr./cm.² (284 lb. per sq. in.) appears to be the limit the Railways consulted think of using in future designs; this limitation is mainly due to the difficulties in building the boilers within a reasonable weight limit, but most often it would appear to be due to other considerations, the most serious of which seems to be the difficulty of using steam at very high temperatures.

III. — Remarks on the maintenance of high-pressure locomotives.

The maintenance of certain high pressure locomotives has given rise to criticisms; it appears that these criticisms do not relate to the pressure itself, but more to the construction of the boilers and the rate of combustion required from such locomotives. It is probably this latter cause which contributes to setting up abnormal expansion, at the same time that the high temperatures reached contribute to the rapid erosion of the sides and stay heads where licked by the flames.

The *French State Rys.* report frequent replacements of stays on their 482.001-039 locomotives the pressure of which has been reduced from 20 to 18 kgr./cm.² (284 to 256 lb. per sq. in.).

On the other hand, the *Alsace-Lorraine Rys.*, on their S.16 locomotives and the *P.L.M. Rys.* on their 4-6-2 class H-141 locomotives, report deformation of the firebox crown and cracks in the crown stays along the sides with ovalisation of the holes into which these stays are fastened in the crown.

The engines in question are all fitted with wide fireboxes with copper inner fireboxes of the Crampton type, with radial stays, without cross stays, of a design in current use in America with steel fireboxes, but little used in Europe.

The damages recorded appear to be the result of lack of rigidity of the firebox, without cross stays, as seem to be required with copper, and also to the defective behaviour of the copper firebox at the high temperatures reached (1).

With a view to overcoming these defects, the *P.L.M. Rys.* have adopted a new firebox, based on that of the *Reichsbahn*, with cross stays secured to the outer firebox casing by separate brackets

(1) See *Revue Générale des Chemins de fer*, May 1936, page 331, article by Mr. CHAN. See also *Bulletin of the Railway Congress*, October 1936.

in order to avoid a continuous line of flexion.

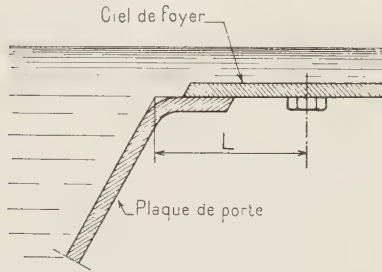


Fig. 1. — Diagrammatic longitudinal section of the back of a firebox.

Note: Ciel de foyer = inner firebox crown plate.
Plaque de porte = inner firebox back plate.

In this new firebox, the *P.L.M. Rys.* have reduced the distance of the last line of vertical stays at the back tube plate by adopting a value $L = 150$ mm. (5 29/32") for it (fig. 1). In the same trend, the radius R , the distances AB

and CD and the angle $\hat{O}$ have been given the following values (fig. 2) :

$AB = CD = 43$ mm. (1 11/16") ;

$R = 125$ mm. (4 29/32") ;

$\hat{O} = 123^\circ$ (2).

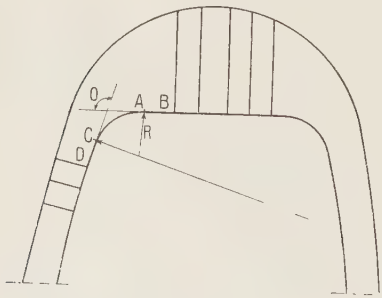


Fig. 2. — Diagrammatic cross section of the outer firebox.

As a comparison with these defects, it should be noted that the *Nord Ry.*, on its 18 kgr./cm.² (256 lb. per sq. in.) pres-

sure locomotives, and the *P.O.-Midi Ry.* on their locomotive with steel fireboxes, and 17 and 20 kgr./cm.² (242 and 284 lb. per sq. in.) pressure, do not report any important damage causing maintenance and inspection difficulties. At the most the former Railway reports unusual wear of the firebox plates and stay heads, due to the rate of combustion which reaches 800 kgr./m²/hour (164 lb. sq. ft./hour) and even exceeds this figure, and the *P.O.-Midi*, leaks at the stay heads of the 4-8-0 locomotives, which have made it necessary to weld the heads and to look for an alloy which would stand up against erosion (*Monel* metal appears to give satisfaction). In the latter case the engines are much forced and the power has been raised from 40 to 100 % relatively to those from which they are developed, with which a rate of combustion of 1 200 kgr./m²/hour (245 lb./sq. ft./hour) with 418° C. (748° F.) of super-heat has been obtained.

Likewise, the *Reichsbahn* has not noted any systematic damage of its high-pressure boilers; the cost of maintenance and the inspection periods are the same as with the lower-pressure engines.

IV. — Use of special alloys in the construction of high-pressure boilers.

The use of these alloys is generally limited to the barrels, the straps and sometimes the stays. The steels used are mostly 2 or 3 % nickel steels, or chrome-copper steels (Table II).

On the other hand, the *Reichsbahn* has freely used special chrome-molybdenum steels and molybdenum steels for its firebox casings; another particular feature is that the parts of the fireboxes of the 20 and 25 kgr./cm.² (284 and 356 lb. per sq. in.) pressure boilers are welded.

As regards the stays, at least those in certain highly stressed areas of the firebox, certain Railways use manganese bronze, copper-nickel alloys, *Monel* metal, or *Stone's* bronze.

(2) The *P.L.M.* endeavoured to obtain the following values, which appeared the optimum values : $AB = CD = 0$. $R = 125$ mm.; angle $\hat{O} = 105^\circ$.

V. — Results obtained.

There is no doubt — and this was pointed out in the report of the 1930 Congress — that the use of high pressures improves the heat efficiency of the boiler and should produce substantial fuel savings. It should be borne in mind that any increase in pressure should be accompanied by an increase in the superheat temperature and a change in the characteristics of the engine (for example : reduction of the diameter of the high-pressure cylinders).

Probably the failure to observe these conditions, is the explanation why certain comparative tests have given the opposite results.

As far as can be gathered from the replies sent, no rigidly comparable tests have been made. We will limit ourselves, therefore, to pointing out that the Reichsbahn with a 25-kgr./cm.² (356 lb. per sq. in.) pressure engine, and 430° C. (806° F.) of superheat, has obtained a

consumption of 0.7 kgr. (1.54 lb.) of coal per indicated horse power hour [consumption related to coal of a lower calorific value of 7000 calories (12 600 B.T.U.)]; however, it would be desirable to know the conditions (power and speed) under which these results were obtained.

VI. — Summary.

1. Increasing the pressure improves the efficiency of the engine, provided the boiler including the superheater and the motion are suitably dimensioned.

2. A boiler pressure of 20 kgr./cm.² (284 lb. per sq. in.) appears to be the maximum that can be currently used at the present time.

CHAPTER II.

Improved water circulation.

I. — Equipment fitted.

The table below indicates the applications of siphons and arch tubes :

Railways.	Number of engines equipped		Characteristics of the equipments.
	with arch tubes.	with Nicholson siphons.	
<i>Austrian Federal Rys.</i>	...	1	Copper firebox.
<i>Finnish State Rys.</i>	22	...	...
<i>Alsace-Lorraine Rys.</i>	2	...	Copper firebox ; 3 mild steel 75/85-mm. tubes.
<i>French Est Rys.</i>	All line engines with the exception of 23.	...	Copper firebox ; 2 or 3 mild steel 76/90-mm. tubes.
	...	23	Steel firebox ; steel siphon.
<i>French State Rys.</i>	...	1	Copper firebox and siphon.
	433	...	Copper firebox ; 2 or 3 mild steel 76/80-mm. or 76/90-mm. tubes.
<i>Nord Ry.</i>	...	20	Steel firebox ; steel riveted siphon.
<i>P.L.M. Rys.</i>	5	...	Copper firebox ; 4 mild steel 76/90-mm. tubes.
	...	1	Copper firebox ; 2 copper siphons.
<i>P.O.-Midi Rys.</i>	...	43	Steel firebox ; steel riveted siphon.

The arch tubes are fastened in the ordinary way by expanding and rolling, with or without grooving the tubes and, on the locomotives of the *P.L.M. Rys.* who have steel firebox tube plates, by a run of electric welding.

II. — Results obtained.

(a) *Arch tubes.*

Opinions are divided :

— the *P.L.M. Rys.* report a 15-minute reduction of the time taken to raise steam, and a reduction of 50 % in the scale on the firebox crown ; the *Est Rys.* find a great improvement in the water circulation in the boiler, and the *Finnish State Rys.* also report satisfactory results ;

— against this, the *French State Rys.* do not find any appreciable improvement.

(b) *Nicholson siphons.*

— the *Austrian Rys.* report a fuel saving of 5 % ;

— the *Est Rys.* have obtained results similar to those with arch tubes ;

— the *Nord Ry.* like the *P.O.-Midi*, think that the Nicholson siphon facilitates heat exchanges and so makes up for the insufficient heating surface due to the development of the superheater, and gives the boiler more flexibility in working ;

— the *P.L.M. Rys.* report a reduction of 25 minutes in the time taken to raise steam and a reduction of over 50 % in the amount of scale on the firebox crown.

III. — Effects on maintenance.

(a) *Arch tubes.*

Although the *Est Rys.* (which have adopted arch tubes on most of their line engines) and the *Alsace-Lorraine Rys.* do not find any particular difficulty in the way of maintenance, the *French State Rys.* report cracks round the holes in the tube plates, making it necessary

to reinforce the latter, and cracks in the tubes along the line on which they are expanded ; the *P.L.M. Rys.*, on their side, have observed, after 200 000 km. (124 000 miles), the formation of blebs 600 mm (2') from the tube plate, due to a reduction in thickness of 2 to 3 mm. (5/64" to 1/8"), which makes it necessary to replace the arch tubes systematically.

(b) *Nicholson siphons.*

The *Nord Ry.* reports deformation of tube plates ; contrariwise, the *P.O.-Midi* have so far reported no damage.

It appears also interesting to note that the *P.L.M. Rys.* from the beginning have used Nicholson siphons in copper, riveted on a firebox with the crown of copper and the tube plate steel. Important leaks occurred through the tube plate not having been made tight ⁽¹⁾, so that the railway had to substitute a copper tube plate for the steel tube plate and weld the siphons by means of « Canzler » metal (fig. 3). Since then the behaviour of the siphons has been satisfactory.

IV. — Summary.

Arch tubes and Nicholson siphons improve the circulation of the water in the boilers and thereby give various advantages (less time taken to raise steam, less scale formation, and increased rate of evaporation). The equipment still requires improvement to avoid the damages reported.

CHAPTER III.

Improvements in combustion.

I. — Grates.

Apart from special grates for « stoker » fireboxes (fig. 4 shows the « Hulson » grate used on the *Nord Ry.*), the grates are still of the usual types : fixed grates,

(1) The riveted joint being in an area subject to serious flexion, due to the expansion of the siphons, was too rigid.

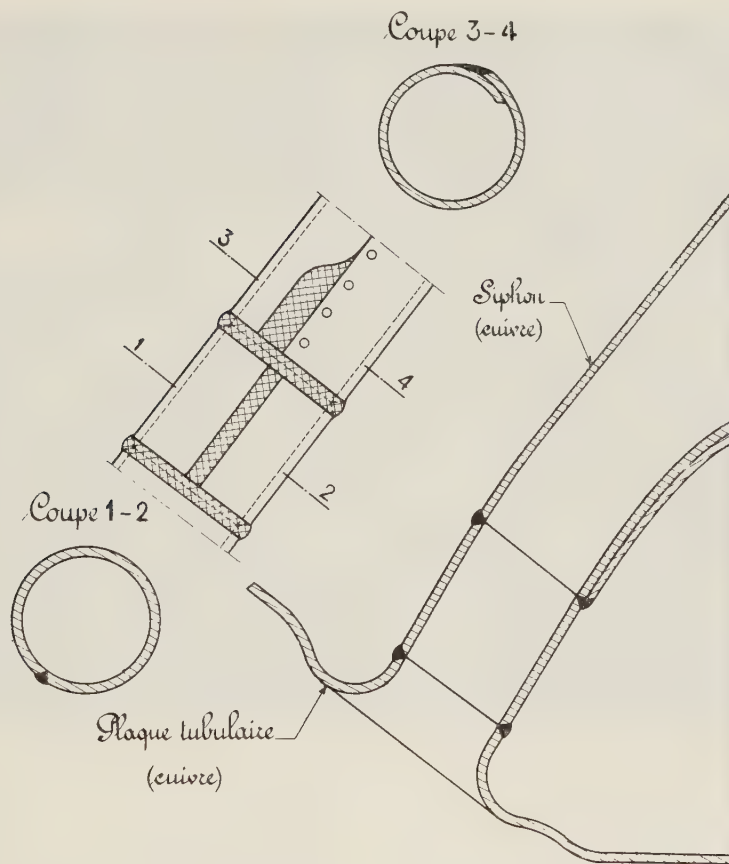


Fig. 3. — Repairing the Nicholson siphon of a *P.L.M.* locomotive, by welding with Canzler metal.

Explanation of French terms:

Coupe 3-4 = section 3-4. — Siphon (cuivre) = siphon (copper).

Plaque tubulaire (cuivre) = Copper tube plate.

shaking grates, or combined. The shaking grates make it possible to use inferior quality coal without difficulty (coal containing a high percentage of ash, even fusible). Their drawbacks are high cost, complication, and the small ratio of the air passages to the grate area (0.35 instead of 0.5 approximately with the fixed grates).

Shaking grates are fitted on all locomotives of the *Belgian National Rys. Co.*, the *P.O.-Midi Rys.*, and the *Hungarian State Rys.*, and on a number of recent locomotives on the *Alsace-Lorraine* and *French State Rys.*

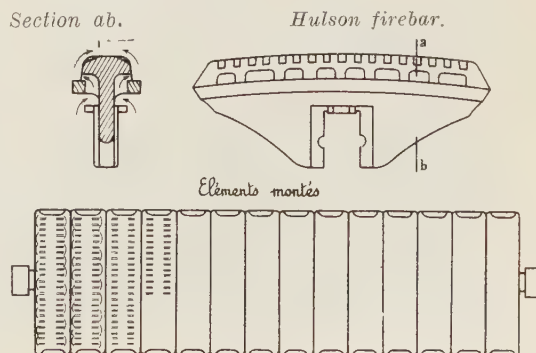


Fig. 4. — Hulson grate as used on the *French Nord Ry.*

Note: Eléments montés = bars as assembled.

II. — Combustion chambers.

Combustion chambers are relatively little used ; the Railway who have adopted them (see Table I) did so with the object of :

- increasing the direct heating surface ;

- mixing the combustion gases from fuel of high volatile content ;

- improving the life of the tube plates ;

- and finally, an accessory advantage, the possibility of moving the centre of gravity of the boiler further forward, and thereby facilitating the distribution of the weight between the driving and carrying axles.

No heat balance-sheet has been supplied with regard to these applications.

III. — Smoke consuming devices.

Since 1930 trials have been made with arrangements to prevent the production of smoke on locomotives ; a number of Railways have even got beyond the experimental stage and are extending the use of devices found satisfactory to a more or less large proportion of their stock.

The arrangements adopted are of various kinds : some meet the wish to obtain automatically as complete as possible freedom from smoke at all times while improving the combustion ; others by means of either automatic or hand control are satisfied to prevent smoke at certain running periods, for example after firing, when running with the regulator closed, etc.

The position on the various Railways at present is as follows :

The *Reichsbahn* and the *Austrian Federal Rys.* have abandoned the use of smoke consuming devices.

The *Belgian National Rys. Co.* is testing the Pyram automatic device ;

The *Alsace-Lorraine Rys.* have obtained good results with this same equipment fitted on an S 16 engine, and are considering

its application to five S 14 engines ;

The *Est Rys.* are carrying out trials with the « Huwyler » arrangement on 2-6-2 tank engine and the automatic Pyram equipment on thirty 2-8-2 tank engines. At the same time they are trying a simplified arrangement of their own design, in which the fire door is open and the blower turned on together while the regulator is closed ;

The *French State Rys.* have recently fitted 10 of their Pacific locomotives with the automatic Pyram equipment ; in addition they are trying an auxiliary blower with double control, which can be operated either by the driver or the fireman ;

The *Nord Ry.* is extending the automatic Pyram equipment to 620 engines of different types, belonging to sheds in the Paris area ;

The *P.L.M. Rys.*, after trying the automatic Pyram device on one 2-8-2 engine, are applying it to five 4-8-4 engines ;

The *Algerian State Rys.* have equipped a number of engines with the Pyram automatic equipment ;

The *Hungarian State Rys.* have applied the Huwyler equipment to 100 locomotives of various classes.

The *Polish State Rys.* are fitting the Pyram smoke consuming device to a number of their locomotives.

Of all the arrangements tested the Pyram automatic device which is an improvement of the « Langer » arrangement appears to be at present the best solution to the problem ; this equipment (fig. 5) consists of an auxiliary blower, a steam nozzle, and an arrangement for admitting additional air through the firehole door ; these parts are controlled by a compressed-air valve which gives the following combinations :

1. with the regulator open, and firehole door closed : the auxiliary blower does not act and the additional air admission

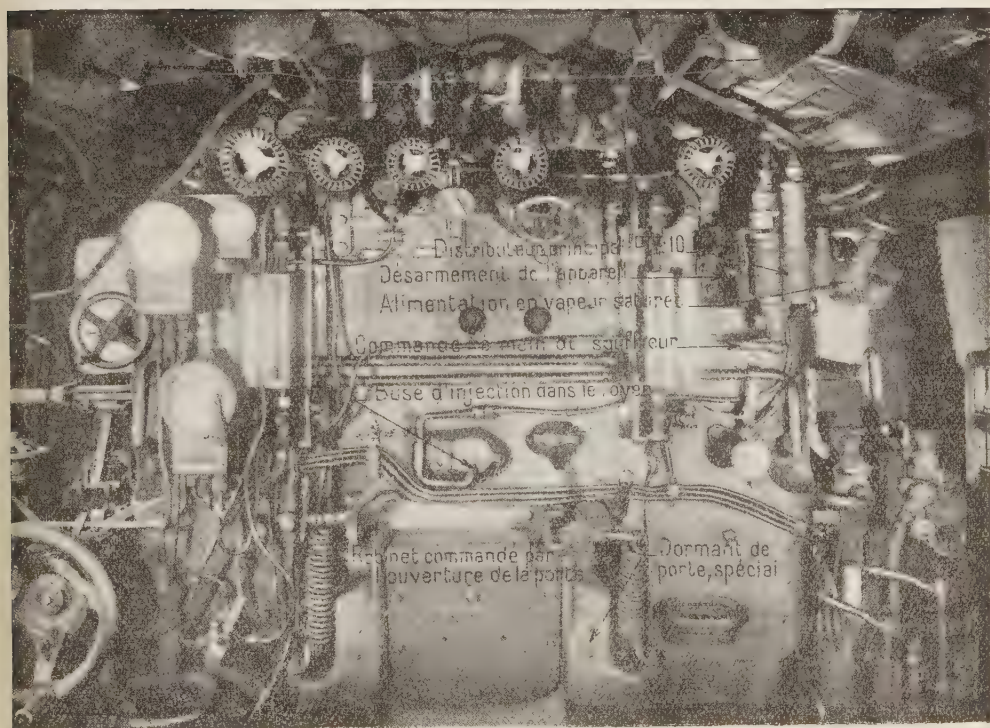


Fig. 5. — P.L.M. locomotive equipped with a *Pyram* smoke consuming device.

is shut off ; the nozzle is fed with superheated steam ;

2. when the regulator is closed, the auxiliary blower comes into action, steam is admitted to the nozzle, and the additional air admission is open ;

3. With the regulator open after firing, the additional air is admitted for 10 to 60 seconds ;

4. with the regulator shut, after the firehole door is closed, the enginemen can cut out the additional blast and close the additional air openings, but only after a time varying from 10 to 60 seconds.

This arrangement is satisfactory from the smoke consuming point of view ; it also prevents blow-backs of the flame ; but it is costly and complicated.

IV. — Soot blowers.

(a) *Equipments fitted.*

Only permanent fittings on the engines will be mentioned. These are of the two following types :

— *fittings which can only be operated when at rest* : « Superior » soot blower of the *Austrian Federal Rys.* and the *Belgian National Rys. Co.* ;

— *fittings which can be operated when running* : the « Superior » (*P.L.M. Rys.*), *Dalmar*, *Diamond*, *C.S.* (steam and sand) (fig. 6).

The following are the appliances in actual use on the different railways and the number of engines fitted :

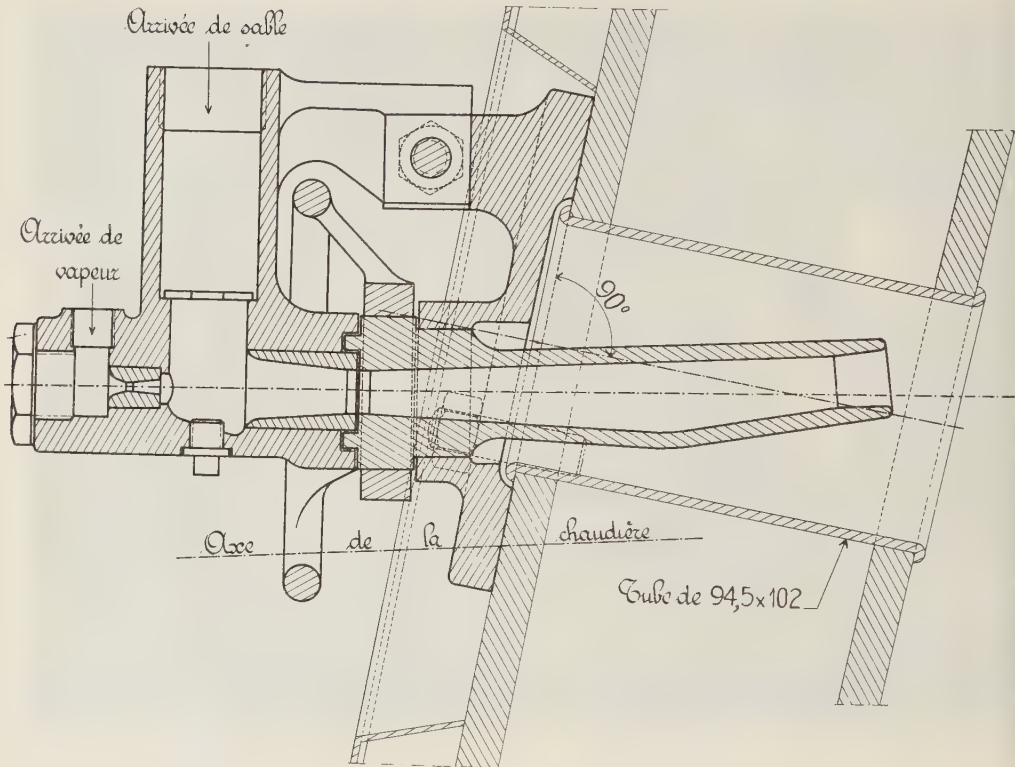


Fig. 6. — CS soot blower with sand jet.

Note : Arrivée de sable = sand supply. — Arrivée de la vapeur = steam supply. — Axe de la chaudière = centre line of boiler.

Austrian Federal Rys. : « Superior », only usable when at rest;

Belgian National Rys. Co. : « Superior » only usable when standing, on all superheated locomotives;

French State Rys. : Dalmar on 80 locomotives, and C.S. on 9 locomotives;

Alsace-Lorraine Rys. : Dalmar, on 4 locomotives and C.S. on 2 locomotives;

Est Rys. : Dalmar, on all recent locomotives;

Nord Ry. : Dalmar, Diamond.

P.O.-Midi Rys. : Dalmar, on 49 locomotives.

P.L.M. Rys. : « Superior » operable when running, on 4 locomotives;

Algerian Rys. (State lines) : Dalmar.

(b) Results obtained.

Taken as a whole, with the exception of the rather unfavourable results obtained on the P.L.M. Rys. on a 4-8-2 large firebox locomotive, all the Railways agree in considering these fittings valuable, as if they do not do away with tube cleaning in the sheds entirely, they reduce the number and extent of such operations. When these fittings are used intelligently they appear of real value on long runs:

The financial balance-sheet based only on the reduction of the time taken to clean tubes in the sheds, also seem favourable; the *Belgian Rys.* report a

saving in labour of 300 000 frs. par annum, with 1500 « Superior » blowers.

The amount of steam used is estimated at about 8 kgr. (17.6 lb.) per operation ; in addition maintenance costs seem to be low.

V. — Measures taken to avoid clogging the grate at high rates of combustion.

Except shaking grates, there are no special devices in use to prevent the grates becoming clogged at high rates of combustion. The Railways consulted have devoted their attention to the following points : mixtures which give the highest point of fusibility with a minimum ash content ; preparing the fire with briquettes or special fuel with a low content of highly fusible ash ; firing rationally to prevent holes in the fire ; as uniform a draught as possible ; firing with small quantities at a time, etc.

As regards fuel, good agglutination is sought after (Belgian Nat. Rys. Co.), also a high temperature of fusion of the ashes (1300° to 1400°C.) and a low ash content.

VI. — Summary.

1. The grates are always of the usual types : either fixed or shaking.
2. Combustion chambers are relatively little used.
3. Some railways are extending the use of smoke consuming devices and soot blowers.

* * *

CHAPTER IV.

Raising the superheat temperature.

I. — Production of superheated steam.

1. Superheat temperatures admitted on the different railways.

All the railways appear to consider 400°C. (752°F.) as the optimum value of the superheated temperature for locomotives

with 16 kgr./cm² (228 lb. per sq. in.) pressure. They thus implicitly admit — although no reply gave any particulars on this subject — that the efficiency of the engine is the maximum at this temperature (below 400°C., in spite of the high temperatures reached, condensation effects still persist in the heart of the mass of steam, especially in the low-pressure cylinders). Starting from this point, locomotives at 20 kgr./cm² (284 lb. per sq. in.) pressure, without intermediate reheating of the steam, should have a superheat temperature of 440°C. (824°F.)

There is no difficulty in obtaining steam of 440° C. and even 450° C. (842° F.). But can it be used in practice, with the metals in contact with the steam and the lubricating oils available? It does not appear practical so far.

In practice the *Est Rys.* use 350° C. (662°F.) in ordinary working for 17 kgr./cm² (242 lb. per sq. in.) pressure, with a maximum of 400°C. (752°F.) ; the *P.L.M. Rys.* 400°C. with 20 kgr./cm² (284 lb. per sq. in.) pressure, and the *Reichsbahn* 400°C. with 16 to 20 kgr./cm² (228 to 284 lb. per sq. in.) pressures.

2. New arrangements adopted and results obtained.

Table III giving the principal characteristics of superheated engines built since 1930 and detailed characteristics of the equipment of the boiler (smoke tubes and superheaters) gives particulars of the results obtained on certain locomotives as the result of a more or less serious alteration of the superheater arrangement.

The following are certain new arrangements and some of the test results obtained :

(a) *Houlet superheater elements.* — These elements which were described in the reports for the 1930 Congress, have been adopted by the *P.O.-Midi* and tested by some other Railways.

(b) *DM.3 superheater elements.* — The *Est Rys.* have altered their DM.4 type elements, also described at the 1930 Congress papers; the new element of the DM. 3. type (fig. 7) has only 3 flat out-

ward tubes and a single circular tube returning to the header; with this arrangement the section of the gas passage is never less than that of the smoke tube where restricted by the back ferrule.

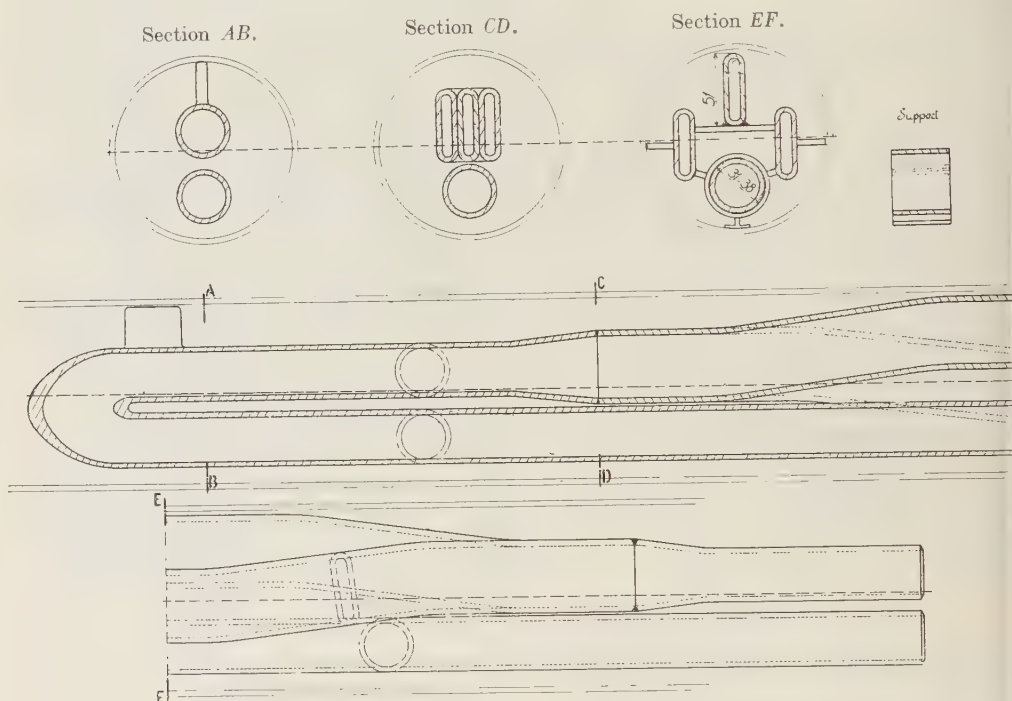


Fig. 7. — DM.3 superheater element, French Est Rys.

Comparative trials on the *Est Rys.* with the DM. 3 and DM. 4 elements on 4-6-2 locomotives, Nos 001 to 040, and 2-10-0, Nos. 141 to 195 locomotives, show that with the DM.3 elements the temperature is about 10°C. (18°F.) higher with superheat temperatures of about 350°C. (662°F.) The increased section of the gas passage has also the effect of practically doing away with the blocking of the tubes sometimes occurring with the DM.4 elements.

(c) *5.P.4 superheater elements.* — The *French State Rys.* have fitted three 4-6-0

locomotives, the *Alsace-Lorraine Rys.* one 4-6-2 (S 16) locomotive, and the *P.L.M. Rys.* one 4-6-2 (H) locomotive with the new 5.P.4 elements of the Superheater Company. These elements have four outward tubes of small diameter and one larger return tube connected at the firebox end to a forged weldless spear end (fig. 8); each of the outward tubes are welded to two wings, which increase the heating surface. With such elements the *Alsace-Lorraine Rys.* have obtained an increase of 35° C. (63° F.) for a final temperature of 410°C. (770°F.) and

Characteristics of the superheaters of recently built or altered locomotives.

ADMINISTRATIONS.	Sequence number.	Class of locomotives.	Simple expansion or compound.	Boiler pressure, (kgr./cm ²)	Grate area (m ²).	Characteristics of the tubes and superheater.											Total heating surface, firebox and tubes (m ²).	Super-heating surface (m ²).	Cross area of gas passages.		Cross area of the steam passages through the super-heater elements. (m ²).	Characteristic ratios.					Superheat temperature, degrees C.			
						Length of tubes (m.)	Smoke tubes.			Superheater tubes.		Superheater.			Distance from back spear heads to firebox tube plate (m.).	through the smoke tubes (m ²).			through the flue tubes across the elements clear of the supports. Ss (m ²).	C/G		Σ/G	Q/G	Σ/C	Ss/Sb	with average firing rates.	When worked heavily.			
							Kind.	Number.	Diameter		Number.	Diameter		Type.														Diameter of superheater elements.		
									Inside (mm.).	Outside. (mm.).		Inside (mm.).	Outside. (mm.).															Inside (mm.).	Outside. (mm.).	
Deutsche Reichsbahn	1	03	S.E.	16	4.05	6.800	Smooth.	84	65	70	20	163	171	Reichsbahn 6 tubes	23	29	0.350	202	70	0.279	0.338	0.0249	49.8	17.2	0.0061	0.346	1.21	385°	400°	
	2	021-04	C.	25	4.10	6.800	...	75	65	70	24	161	171	do.	23	29	...	206.8	84.6	0.249	0.393	0.0299	50.4	20.6	0.0073	0.409	1.57	420°	430°	
	3	71	S.E.	20	1.37	3.500	...	70	39.5	44.5	26	110	118	do.	23	29	...	67.4	28.6	0.086	0.144	0.0324	49.1	20.8	0.0236	0.424	1.67	...	...	
	4	172	C.	25	2.85	4.900	...	94	45	50	36	130	138	do.	23	29	...	152.65	76.41	0.149	0.335	0.0448	53.5	26.8	0.0157	0.500	2.24	420°	...	
	5	05	S.E.	20	4.70	7.000	...	106	65	70	24	163	171	do.	23	29	...	256	90	0.352	0.406	0.0299	54.4	19.1	0.0064	0.351	1.15	420°	...	
	6	61	S.E.	20	2.75	5.000	...	88	49	54	33	135	143	do.	23	29	...	151.9	69.2	0.166	0.336	0.0411	55.2	25.1	0.0149	0.455	2.02	...	...	
	7	84	S.E.	20	3.76	4.700	...	158	46	51	48	125	133	do.	23	29	...	210.10	85	0.262	0.399	0.0598	56.1	22.6	0.0159	0.404	1.52	...	...	
	8	44	C.	25	4.70	5.800	...	83	55	60	43	143	152	...	...	...	...	220.4	109.7	...	...	...	...	...	...	...	...	...	...	
Austrian Federal Rys.	9	114	S.E.	15	4.72	6.000	...	151	51.5	57	38	135	143	Schmidt.	...	...	0.400	262	77.8	0.314	...	...	55.5	16.4	...	0.296	...	...	...	
	10	214	S.E.	15	4.72	6.000	...	151	51.5	57	38	135	143	do.	...	...	0.400	262	77.8	0.314	...	...	55.5	16.4	...	0.296	...	...	430°	
	11	729	S.E.	13	3.55	4.900	...	156	48	53	22	125	133	do.	...	...	...	171.3	41.1	0.282	...	...	48.2	11.5	...	0.239	...	...	...	
	12	D.T.1	S.E.	16	0.83	3.265	...	35	37	41.5	24	100.5	108	do.	...	...	...	42.48	16.47	0.038	...	...	51.1	19.8	...	0.387	...	...	...	
Belgian National Rys. Co.	13	5	S.E.	14	5.5	6.000	...	170	50	55	43	128	137	Belge Flamme	30.5	38	0.450	284	112	0.334	0.358	0.0314	51.6	20.3	0.0057	0.394	1.07	...	...	
	14	35	S.E.	14	5.07	4.500	...	182	45	50	43	128	137	Schmidt.	30.5	38	0.420	214	91	0.289	0.358	0.0314	42.2	17.9	0.0062	0.425	1.22	...	...	
	15	1	S.E.	18	5	6.000	...	131	50	55	38	128	137	do.	30.5	37.5	0.300	235	112	0.257	0.321	0.0278	47.0	22.4	0.0056	0.476	1.25	375°-385°	410°	
	16	7	C.	16	3.08	4.400	...	122	45	50	35	125	133	do.	30.5	38	0.300	168	68.5	0.194	0.271	0.0256	54.5	22.2	0.0083	0.408	1.40	375°	400°	
English Electric Co.	17	P1	S.E.	15	3.54	6.000	...	119	51.5	57	26	135	143	...	...	...	...	195.4	68	0.248	...	...	55.2	16.2	...	0.348	...	...	...	
	18	S.14	1st arrangement.	C.	17	4.27	5.900	...	136	45	50	24	130	138	Schmidt.	31	38	...	211.97	63.5	0.216	0.210	0.0181	49.6	14.9	0.0042	0.299	0.972	358°	...
American Rys. Co.	19	S.16	2nd arrangement.	C.	17	4.27	5.900	...	136	45	50	24	130	138	do.	31	38	...	211.97	63.5	0.216	0.210	0.0181	49.6	14.9	0.0042	0.299	0.972	358°	...
	20	G.16	1st arrangement.	S.E.	20	4.56	5.905	Smooth.	137	50	55	30	140	148	Schmidt.	31	38	0.300	223.7	73.8	0.269	0.226	0.0226	49.7	16.4	0.0056	0.350	1.21	365°	...
French Rys.	21	231.001 to 040	2nd arrangement.	S.E.	20	4.56	5.905	do.	137	50	55	30	140	148	5 P1	16	24	0.300	223.7	...	0.417	0.382	0.0183	49.7	...	0.0041	...	0.92	410°	...
	22	231.001 to 040	3rd arrangement.	do.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	23	231.001 to 040	3rd arrangement.	do.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	24	231.001 to 040	3rd arrangement.	do.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	25	231.001 to 040	3rd arrangement.	do.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	26	231.001 to 040	3rd arrangement.	do.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	27	231.001 to 040	3rd arrangement.	do.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	28	231.001 to 040	3rd arrangement.	do.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	29	231.001 to 040	3rd arrangement.	do.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
	30	231.001 to 040	3rd arrangement.	do.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	
31	231.001 to 040	3rd arrangement.	do.	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...		



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TABLE III. (Continued.)

ADMINISTRATIONS.	Sequence number.	Class of locomotives.	Simple expansion or compound.	Boiler pressure, kgr./cm^2	Grate area G (m^2).	Characteristics of the tubes and superheater.												Total heating surface, firebox and tubes C (m^2).	Super-heating surface Σ (m^2).	Cross area of gas passages.		Cross area of the steam passages through the super-heater elements. Q (m^2).	Characteristic ratios.					Superheat temperature, degrees C.	
						Length of tubes (m.)	Smoke tubes.			Superheater tubes.		Superheater.			through the smoke tubes Sb (m^2).	through the flue tubes across the elements clear of the supports. Ss (m^2).				C/G	Σ /G		Q/G	Σ /C	Ss/Sb	At average firing rates.	When worked heavily.		
							Kind.	Number.	Diameter		Number.	Diameter		Type.														Diameter of superheater elements.	
									Inside (mm).	Outside (mm).		Inside (mm).	Outside (mm).															Inside (mm).	Outside (mm).
French State	27	151.001 to 010	S.E.	14	3.25	5.000	...	148	50	55	32	130	138	DM ³	31 + ret. 15	38	...	203.26	81.14	0.290	0.254	0.0241	62.5	25.0	0.0074	0.399	0.87	...	...
	28	231.523	S.E.	16	4.27	5.900	...	151	50	55	24	125	133	Schmidt.	31 + ret. 15	51	...	211.97	63.5	...	...	...	...	...	...	...	...	...	...
	29	241.001 to 049	C.	20	4.43	6.000	Smooth.	130	50	55	30	130	138	DM ³	31 + ret. 15	38	...	223.20	94.20	0.255	0.300	0.0226	50.4	21.3	0.0051	0.422	1.18	...	...
	30	241.101	S.E.	20	5	6.300	Serve.	20	50	55	30	140	148	Schmidt.	31 + ret. 15	51	...	268.35	85.65	0.314	0.326	0.0226	53.7	17.1	0.0045	0.319	1.00	...	...
	31	42.101 to 140	S.E.	14	2.80	4.300	Smooth.	91	65	70	30	140	148	Schmidt.	31 + ret. 15	38	...	139.63	35.98	0.224	0.151	0.0158	49.7	12.8	0.0056	0.258	0.67	...	...
	32	231.501 to 783	C.	16	4.27	5.900	do.	125	50	55	28	125	133	Houlet.	31 + ret. 15	38	...	197.17	83	0.245	0.233	0.0222	46.2	19.4	0.0052	0.42	0.95	400°	...
French Nord							do.	119	50	55	30	125	133	Houlet.	31 + ret. 15	38	...	197.84	88.92	0.234	0.250	0.0238	46.3	20.8	0.0056	0.45	0.95	440°	...
							do.	119	50	55	30	125	133	Schmidt.	31 + ret. 15	38	...	197.84	64.96	0.234	0.253	0.0184	46.3	15.21	0.0043	0.33	1.08	390°	420°
							do.	119	50	55	30	125	133	Schmidt.	31 + ret. 15	38	...	197.84	76.58	0.234	0.232	0.0226	46.3	17.9	0.0053	0.39	1.00	380° (S.C.)	390° (S.C.)
	33	3.1251 to 1290	C.	17	3.48	4.550	do.	36	45	50	32	135	143	Schmidt.	31 + ret. 15	38	0.250	195.98	61.01	0.252	0.294	0.0241	56.31	17.5	0.0069	0.31	1.16	375°	397°
	34	4.1207 to 1272	S.E.	18	3.087	4.805	Smooth.	65	45	50	32	135	143	Schmidt.	31 + ret. 15	38	...	203.33	64.25	0.252	0.294	0.0241	65.9	20.8	0.0078	0.31	1.16	...	...
	35	5.1201 to 1230	C.	18	3.48	4.550	Serve.	65	45	50	32	135	143	Schmidt.	31 + ret. 15	38	...	195.98	61.01	0.252	0.294	0.0241	56.31	17.5	0.0069	0.31	1.16	375°	397°
P.L.M. Rys.	36	241 C 1	C.	20	5.006	5.988	Smooth.	141	51	55	33	135	143	Schmidt.	31 + ret. 15	38	0.150	248	91.30	0.288	0.345	0.0203	49.5	18.2	0.0040	0.37	1.20	...	...
	37	242.CT 1 to 50	C.	16	3.08	5.000	do.	12	51	55	21	135	143	Schmidt.	31 + ret. 15	38	0.450	172.92	45.47	0.212	0.220	0.0129	56.1	14.8	0.0042	0.37	1.20	...	...
	38	242.DT 1 to 50	C.	16	4.25	6.000	Serve.	62	65	70	26	135	143	Schmidt.	31 + ret. 15	38	0.450	206.25	68.29	0.261	0.272	0.0160	48.5	16.1	0.0038	0.37	1.20	...	...
	39	141.C 501 to 680	C.	16	4.25	6.000	Smooth.	128	51	55	26	135	143	Schmidt.	31 + ret. 15	38	0.450	206.25	68.29	0.261	0.272	0.0160	48.5	16.1	0.0038	0.37	1.20	...	...
	40	241.A 126 to 145	C.	16	5	5.988	do.	143	51	55	33	135	143	Schmidt.	31 + ret. 15	38	0.450	246.16	86.55	0.292	0.345	0.0203	49.2	17.3	0.0041	0.37	1.20	...	...
	41	241.D	C.	16	5	5.988	do.	141	51	55	33	135	143	Schmidt.	31 + ret. 15	38	0.450	246.16	86.55	0.292	0.345	0.0203	49.2	17.3	0.0041	0.37	1.20	...	...
P.O.-Midi Rys.	42	151.A-1 to 10	C.	20	5	0.5988	do.	141	51	55	33	135	143	Schmidt.	31 + ret. 15	38	0.450	243.77	91.64	0.288	0.345	0.0203	48.75	18.3	0.0040	0.37	1.20	...	...
	43	231.H. 141	C.	20	4.25	6.060	do.	124	51	55	26	141	150	5 P ⁴	31 + ret. 28	35	0.350	203.82	44.58	0.253	0.315	0.0185	47.9	10.5	0.0043	0.22	1.24	...	390° (S.C.)
	44	231.G-231 to 285	C.	16	4.25	6.060	do.	128	51	55	26	135	143	Schmidt.	31 + ret. 28	35	0.450	206.25	44.58	0.261	0.272	0.0160	48.5	10.5	0.0038	0.216	1.04	...	390°/400°
	45 A	231.701	C.	17	4.33	5.900	do.	80	50	55	32	125	133	Robinson.	31 + ret. 28	38	...	184.71	72.85	0.202	0.248	0.0241	43.2	16.8	0.0056	0.394	1.23	350°	400°
	45 B	231.702 to 721	C.	17	4.33	5.900	do.	125	50	55	28	125	133	Houlet.	31 + ret. 28	35	...	198.33	80	0.244	0.231	0.0257	45.8	18.5	0.0059	0.394	1.23	...	...
	46	231.722 to 731	C.	17	4.33	5.900	do.	125	49	54	28	125	133	Houlet.	31 + ret. 28	35	...	197.085	80	0.236	0.230	0.0225	45.5	18.5	0.0052	0.394	1.23	...	...
Algerian Rys.	47	240.701	C.	20	3.76	4.250	do.	29	39.5	44.5	28	125	133	Houlet.	31 + ret. 28	40	...	215.90	60.60	0.239	0.241	0.0237	57.42	16.1	0.0063	0.281	1.07	...	420°
	48	240.702 to 712	C.	20	3.76	4.250	Serve.	67	65	70	8	65	70	Schmidt.	31 + ret. 28	35	...	213.61	67.02	0.257	0.238	0.0241	56.8	17.8	0.0064	0.314	0.93	...	410°
	49	240.702 to 712	C.	20	3.76	4.250	Smooth.	86	39.5	44.5	30	125	133	Houlet.	31 + ret. 28	40	...	213.61	67.02	0.257	0.238	0.0241	56.8	17.8	0.0064	0.314	0.93	...	410°
	50	240.702 to 712	C.	20	3.76	4.250	Serve.	86	60	65	30	125	133	Houlet.	31 + ret. 28	40	...	213.61	67.02	0.257	0.238	0.0241	56.8	17.8	0.0064	0.314	0.93	...	410°
	51	231.132 AT	S.E.	16	5.07	4.570	...	232	44	50	50	125	133	Schmidt.	31 + ret. 28	35	0.375	258.25	69	0.353	0.412	0.0308	50.9	13.6	0.0061	0.297	1.17	...	...
	52	231.132 BT	S.E.	20	5.40	4.590	...	225	46	51	48	130	138	Schmidt.	31 + ret. 28	35	...	259.60	90.60	0.342	0.452	0.0296	48.1	16.8	0.0055	0.349	1.32	...	...
Hungarian State Rys	53	424	S.E.	13	4.45	5.000	...	178	46.5	52	28	125	133	...	31 + ret. 28	39	0.500	220.50	55.70	0.302	0.210	0.0225	49.5	12.5	0.0050	0.252	0.69	...	...
	54	6 300	S.E.	14	3.16	4.500	Smooth.	158	45	50	28	125	133	...	31 + ret. 28	38	...	168	50	0.251	0.216	0.0211	53.2	15.8	0.0067	0.297	0.86	...	...
	55	Pu. 29	S.E.	15	4.80	6.110	...	103	65	70	26	157	165	...	31 + ret. 28	39	...	238	86.80	0.342									

Section AB.

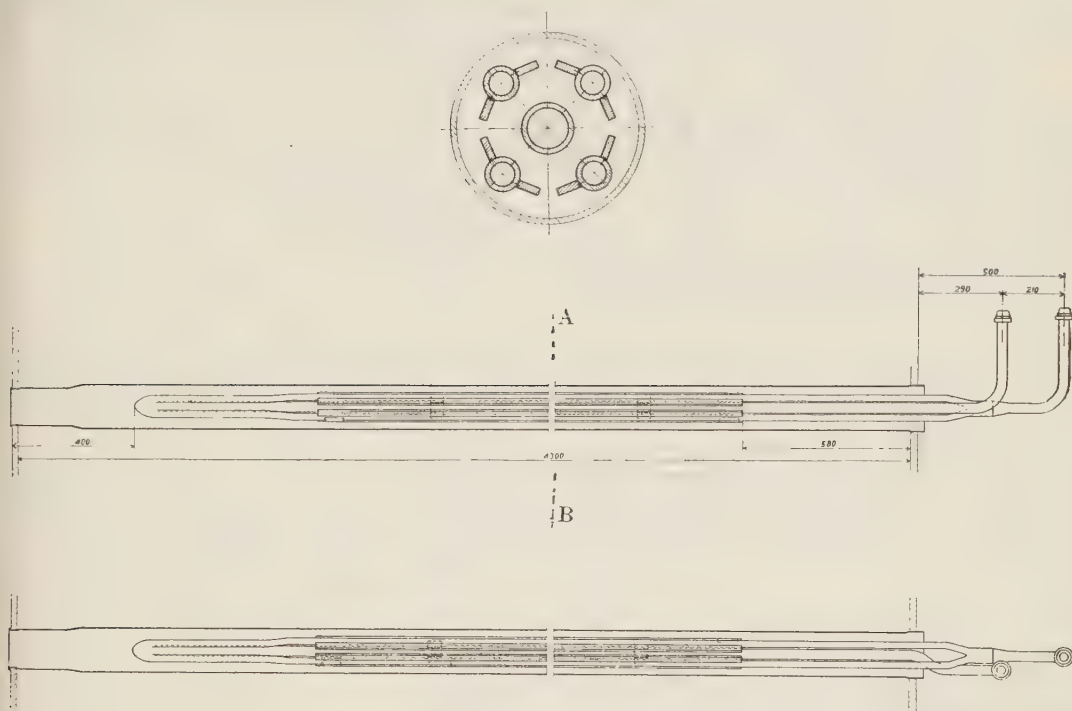


Fig. 8. — Type 5 P 4 superheater element.

P.L.M. Rys. an increase of 25°C. (45°F.) and a final temperature of 390°C. (734°F.) (1).

(d) *Headers with separate chambers.* — Headers with separate chambers have been put into use on most Railways; comparative tests carried out on the *Alsace-Lorraine Rys.* show increases in temperature varying between 12 and 25°C. (21.6 and 45°F.) according to the type of locomotive. These headers have the advantage of being simple, preventing the steam being short circuited and heat exchanged between the saturated

and superheated steam chambers, and of compensating to some extent the difference of expansion of the outward and the return tubes. Against this, they take more room and it is more difficult to find place for them in the smoke box, and involve an alteration in the existing elements.

3. Opinions of the railways on the future design of superheaters.

These opinions are summed up in Table IV.

The railways agree that superheaters with large tubes and with separate headers should be used. Special elements (Houlet, DM, 5.P.4) are often used to obtain high superheat temperatures.

(4) In the case of the *P.L.M.*, the elements are the 5.P.4 special type, that will be referred to later on when dealing with feed water preheating.

Arrange

ADMINISTRATIONS.	General arrangement of the superheater.	Type of superheater.	Distance of space from the firebox plate. (millim.)
<i>Deutsche Reichsbahn</i>	Flues.	Deutsche Reichsbahn (6 flues)	350
<i>Austrian Federal Rys.</i>	Flues.	Deutsche Reichsbahn.	...
<i>Belgian National Rys. Co.</i>	Flues.	Schmidt.	300 to 420
<i>Alsace-Lorraine Rys.</i>	Flues.	Schmidt or 5P4.	300 for 5P4
<i>Est Rys.</i>	Flues.	DM3.	450 to 600 according to 1
<i>French State Rys.</i>	Flues.	...	...
<i>Nord Ry.</i>	Flues.	Schmidt.	250 on 31.200 cl
<i>P.L.M. Rys.</i>	Flues.	Schmidt on locom. without economiser. 5P4 on locom. with economiser.	450 for Schmidt s 350 for 5P4 ele
<i>P.O.-Midi Rys.</i>	Flues.	Houlet.	...
<i>Algerian Rys.</i>	Flues.	Schmidt.	375
<i>Damas Hamah Ry. and Extensions.</i>	Flues.	Schmidt.	...
<i>Hungarian State Rys.</i>	Flues.	...	500
<i>Netherlands Rys.</i>	...	Schmidt.	500
<i>Polish State Rys.</i>	...	...	...

I. — Lubrication of valves and pistons.

1. Oils used.

We have collected in Table V the principal specifications of the oils used by the different railways to lubricate superheated engines; the variety of the superheat temperatures and the mechanical arrangements of the engines have resulted in an equally great variety of oil specifications.

These oils are giving satisfaction to the Railways using them, except on the *P.L.M.*, the *Polish State*, and the *Netherlands Rys.*

As a general rule, no lubricant other than oil is used; in the case of high superheat, either pure mineral oils, or compound oils (the flash point of which is slightly lower) are used, all these oils having the lowest possible asphalt and ash content.

superheaters.

Shape of supports and stays.	Superheated temperature, degrees C.	Ratios to be observed.
...	420° to 430° for 25 kgr./cm ² . 400° for 16 kgr./cm ² .	...
...	Over or equal to 400°.	...
...	...	Cross sectional area of the passages through the superheater elements Cross sectional area of the smoke tubes = 1.5.
...	400° for 20 kgr./cm ² .	...
support, welded slide shoes.	Maximum 400°; normal 350° for 17 kgr./cm ² .	...
...	...	...
right round element.	400° for 18 kgr./cm ² .	Superheater surface Total tube heating surface = 0.35 to 0.45
...	400°	...
Welded slide shoes.	...	...
right round element.	...	Resistance of the superheater elements Resistance of the smoke tubes = 0.16
...	...	Cross sectional area of the gas passages through the superheater elements Cross sectional area of the gas passages through the smoke tubes = 1.30
m. strap and slide shoes.	350°	Tube heating surface Tube cross sectional area ≤ 500.
...	...	...
...	400° for Fy 23 locom. 370°-380° for Pu 29-Pt 31 loc. 350° for O.Kz-32 locom.	...

2. Method of lubricating the different parts.

a) Types of lubricators used.

Table VI gives particulars of the lubricators used by the different railways; a general tendency will be noticed towards the use of mechanical lubricators on new locomotives or those recently rebuilt. These lubricators are all of known designs and have already been described elsewhere.

These lubricators usually are fitted with retaining valves of different patterns, to prevent the pipes becoming empty when the regulator is shut, and to reduce as far as possible the pressure to be overcome by the lubricator. As an exception, the *Est Rys.* continue to admit steam and use capillary orifices of the Bernard & Poncet system, as described in the reports to the Madrid Congress. The *Nord Ry.* is following the same practice, as

this company, being none too satisfied with mechanical retaining valves, is testing the capillary device of the Est Rys.

So as to prevent as far as possible oil carbonising in contact with the highly superheated steam and also to finely break up the lubricant, some railways use in conjunction with mechanical retaining valves, anticarbonisers which pulverise the oil by injecting steam; the usefulness of these devices is questioned: the *P.L.M.*, for example, has given them

up, whilst other Railways are using them generally, at least for the lubrication of the valves and high-pressure cylinders.

b) General lubrication arrangements.

Very widely different lubricating arrangements are used according to the number of parts to be lubricated, as well as the type of valve gear, degree of superheat, etc.

The *Est Rys.*, wishing to increase the number of points lubricated, have ap-

TABLE VI.

Types of lubricators and retaining valves used for lubricating cylinders and valves.

ADMINISTRATIONS.	Type of lubricator		Retaining device.
	sight-feed.	mechanical.	
<i>Deutsche Reichsbahn</i>	...	Bosch-Reichsbahn.	Woerner.
<i>Austrian Federal Rys.</i>	...	Friedmann.	Olva.
<i>Belgian Nat. Rys. Co.</i>	...	Zeyen.	Ball type.
<i>Finnish State Rys.</i>	...	Friedmann.	...
<i>Alsace-Lorraine Rys.</i>	...	Wakefield-Martin.	Various types.
<i>Est Rys.</i>	...	Bourdon.	Bernard & Poncet device with capillary connection and added steam.
<i>French State Rys.</i>	Detroit.	Bourdon. Bosch. Wakefield.	Olva.
<i>Nord Ry.</i>	...	Bourdon. Martin. Bosch.	With clap valve or Bernard & Poncet device with capillary connection and added steam.
<i>P.L.M. Rys.</i>	...	Bourdon.	Olva.
<i>P.O.-Midi Rys.</i>	...	Bosch.	Woerner.
<i>Algerian State Rys.</i>	...	Wakefield. Bourdon.	Olva.
<i>Damas-Hamah Ry. and Extensions</i>	...	Friedmann.	Friedmann.
<i>Hungarian State Rys.</i>	...	Friedmann.	Olva.
<i>Netherlands Rys.</i>	...	Friedmann.	Olva.

TABLE V.

Characteristics of superheater oils used.

Description.	Purpose.	Tar content, %	Asphalt content, %	Ash content, %	Specific gravity		Maximum congealing point.	Inflammability.			Fluidity (F) or Viscosity (V).					Acidity.	Saponification factor or content of saponifiable matter.	Source of supply and particular remarks.
					at the tempe- rature of	value of the gravity.		Instrument measured by	Flash point, degrees C.	Minim. combust. tempera- ture, de- grees C.	Viscometer used.	at 20° C.	at 50° C.	at 100° C.	at 200° C.			
GERMANY.																		
Deutsche Reichsbahn.																		
	High superheat.	...	[0.01 to 0.05]	...	...	0.90	...	...	[345°, 350°]	...	(V).	...	...	7° to 9°	...	...	...	
AUSTRIA.																		
Federal Railways.																		
Heissdampfzylinderöl	All superheat temperatures.	...	< 0.05	< 0.06	15° C.	< 0.910	...	...	> 310°	...	(V) Engler.	...	...	5° to 6°	...	...	Pure mineral oil .	
BELGIUM.																		
Belgian National Railways Co.																		
No special designation	Average superheat.	0.03	< 0.30	0.10	20° C.	about 0.900	> — 2°	Closed crucible.	> 275°	...	(V) Vogel-Ossag.	528	46.5	5°	...	0.05 %-SO ₂	...	95 to 96.5 % natural petroleum oil, and 3 to 5 % of saponifiable oil or grease. Neutral to coloured re- agents. { Pure mineral oil. (1) Conradson carbon
A oil	High superheat.	...	0.05	3 (1)	20° C.	0.899	+ 8°	...	313°	...	»	706	61	6.6	...	0.002 %-SO ₂	...	
B oil	Do.	...	0.02	3.2 (1)	20° C.	0.902	+ 6°	...	295°	...	»	660	57	6.36	...	Traces.	...	
FRANCE, COLONIES AND PROTECTORATES.																		
Alsace-Lorraine Railways.																		
Cg.2 (S.T.U. No. 179)	Superheat < 350° C.	...	..	< 0.10	15° C.	0.900	...	Pensky Martens.	> 275°	...	(F) Barbey.	...	...	< 180	< 1000	Index < 2.5	2.5 < index < 10	Mechanical impurities < 0.10
Cg.4 (S.T.U. No. 179).	Superheat > 360° C.	...	...	< 0.10	15° C.	0.910	...	Pensky Martens.	> 300°	...	(F) Barbey.	...	...	< 90	< 700	Index < 2.5	2.5 < index < 10	Mechanical impurities < 0.10 %.
Gargoyle super cylinder oil « Extra Hecla », Vacuum Oil Company. .	High superheat.	...	Traces.	Traces.	15° C.	0.9008	...	...	270°	...	(F) Barbey.	...	...	135	825	...	Index 12.9	...
Est Railways.																		
Cg.2 (S.T.U. No. 179)	Average superheat.	...	< 0.4	< 0.10	15° C.	0.90 to 0.93	...	Pensky Martens.	> 275°	...	(F) Barbey.	...	...	< 180	< 1000	Index < 2.5	2.5 to 10	...
Cg.3 (S.T.U. No. 179)	Do.	...	< 0.5	< 0.10	15° C.	0.90 to 0.93	...	Pensky Martens.	> 290°	...	(F) Barbey.	...	...	< 120	< 800	Index < 2.5	2.5 to 10	...
...	High superheat.	...	...	Nil.	15° C.	0.90	+ 3°	Pensky Martens.	295°	...	(F) Barbey.	...	...	...	...	0.3 to 0.4	8 to 9	...
French State Railways.																		
Special Galéna 136, superheater oil.	High superheat.	...	0.17	Traces.	15° C.	0.920	...	Luchaire.	271°	...	(F) Barbey.	at 35° 7	at 56° 24	143	...	0.32 % oleic acid.	Content 6.5 %	...
Ordinary Galéna superheater oil. .	Do.	...	0	0.005	15° C.	0.909	...	Luchaire.	272°	...	(F) Barbey.	5	24	153	...	0.5 % oleic acid.	Content 3.76 %	...
Ordinary « Consommateurs de pé- trole » superheater oil.	Do.	...	0.5	0.5	15° C.	0.902	...	Luchaire.	261°	...	(F) Barbey.	2	20	150	...	0	Content 11.5 %	...

TABLE V. (Continued.)

Description.	Purpose.	Tar content, %	Asphalt content, %	Ash content, %	Specific gravity		Maximum congealing point.	Inflammability.			Fluidity (F) or Viscosity (V).					Acidity.	Saponification factor or content of saponifiable matter.	Source of supply and particular reactions.
					at the tempe- rature of	value of the gravity.		Instrument measured by	Flash point, degrees C.	Minim. combust. tempera- ture, de- grees C.	Viscometer used.	at 20° C.	at 50° C.	at 100° C.	at 200° C.			
Nord Railway.																		
Ordinary superheater oil. Super Extra Hécla-Oléovalvo V4X « Consommateurs de pétrole » C 45-55.	Average superheat. 400° C. Superheat	{	...	...	...	...	No exact particulars.	S.T.U. No. 179.	...	...	...	...	...	...	...	...	...	
Paris-Lyon-Méditerranée Railways.																		
Cg.3 (S.T.U. No. 179)	...	...	< 0.5	< 0.10	...	...	...	...	> 290°	...	(F) Barbey.	...	...	190-120	< 800	Index < 2.5	2.5 to 3.0	
P.O.-Midi Railways.																		
C.4 (S.T.U. No. 179) 98/95 S/u « Consommateurs de pé- trole » « Extra Hécla » of the « Vacuum Oil Company »	< 300° C. superheat. 300 to 350° C. superheat ...	...	< 0.5	< 0.10 0.015 0.002	15° C. 15° C.	0.911 0.904	... ... ...	... Luchaire. Luchaire.	> 308° 265° 310°	... 335° 340°	(F) Barbey. (F) Barbey. (F) Barbey.	... ... ...	... ... ...	< 90 82 95	< 700 680 73.5	< 2 1 12 (2)	 (2) Combined acidity and saponifi- cation indices.	
Algerian Railways.																		
CN.31 « Consommateurs de pétrole » « Extra Hécla » of the « Vacuum Oil Company »	Ordinary superheated locomotives. ...	...	... ...	... 0.002	15° C.	0.904	... ...	... Luchaire.	... 310°	... 340°	... (F) Barbey.	... ...	... ...	... 95	... 73.5	... 12 (2)	... (2) Combined acidity and saponifi- cation indices.	
Damas-Hamah Railway and Extensions.																		
C.4 (S.T.U. No. 179)	All superheat temperatures.	...	< 0.5	< 0.10	...	...	...	...	> 308°	...	(F) Barbey.	...	...	< 90	< 700	Index < 2.	...	
HUNGARY.																		
Royal Hungarian State Railways.																		
Pennsylvania oil.	...	...	...	...	15° C.	0.907	> + 5°	Open crucible.	327°	...	(V)	{ below 80° : 1 poise. above 250° : 0.025 poise.			...	...	...	
NETHERLANDS.																		
Netherlands Railways.																		
Mineral oil.	...	...	Traces.	Nil.	15° C.	0.910	...	...	> 220°	...	(V) Engler.	...	...	6° to 7°	...	< 0.50-SO ₃ .	...	
POLANDS.																		
Polish State Railways.																		
...	...	< 2 %	< 0.1 %	< 0.1 %	15° C.	0.920	...	Open crucible.	> 310°	...	(V) Engler.	...	...	5° to 6°	...	...	...	

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plied the arrangement shown in fig. 9, by which the lubricating pipes are doubled in number whilst equally well

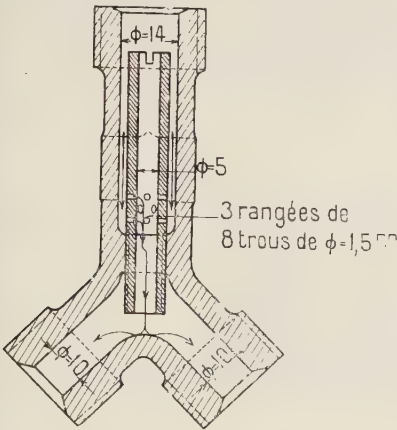


Fig. 9. — Method used on the *French Est* for splitting up lubricating pipes.
Note: 3 rangées... = 3 rings of 8 holes, 1.5 mm. in diameter.

distributing the oil in the by-pass tubes; for a satisfactory result the following rules must however be observed :

- the common branch should be vertical ;
- the pipe to the common branch should be extended by a straight part 10 cm. (4") in length next to the common branch pipe.

By doing this, the *Est Rys.* have been able to retain their old lubricators with 4 feeds, whilst increasing the number of points lubricated.

These arrangements, however, seem to be only makeshifts. The tendency is more and more towards providing a separate feed for each point to be lubricated, by multiplying the number of these points; this leads to the use of mechanical lubricators with a large number of feeds (20 or more) to which can be confided not only the lubrication of the cylinders, valve gear, piston and tail rod packings, but also the mechanism of the auxiliary machines (air pump, water pump, etc.).

The number of combinations therefore is very high and each Railway has its own ideas according to the type of engine to be equipped.

Poppet valve engines. — Valve gear.

The method of lubricating the valve gear depends essentially on the gear used; consequently no general rule can be formulated.

c) Consumption of lubricating oil.

The table below summarises the consumption of cylinder oil for the different workings covered.

Railway.	Type of lubrication.	Consumption of cylinder oil, in grammes per kilometre			
		Express services.	Fast services.	Goods services, heavy and express.	Ordinary passenger services or light goods.
<i>Austrian Federal Rys.</i> . . .	Mechanical	4	...	...	...
<i>Belgian Nat. Rys. Co</i> . . .	...	...	...	...	...
<i>French Railways</i>	Mechanical	9 to 20		7 to 20	7 to 12
<i>Algerian Railways</i>	Do.	20	20	...	...
<i>Netherlands Railways</i> . . .	Do.	7.28 to 10.9		...	...
<i>Hungarian State Rys.</i> . . .	Do	41.21	15.41 to 19.65	19.85	19.85

III. — Piston rings.

(a) Characteristics of the rings.

The increase in speeds, pressures, and superheat temperatures has made the behaviour of piston rings one of the main preoccupations of the railways.

We have collected in Table VII particulars of the rings used by the different Railways consulted; we have also shown in figure 10, for comparison, curves giving the thickness of the rings relative to the diameter. The curves are very close one to the other.

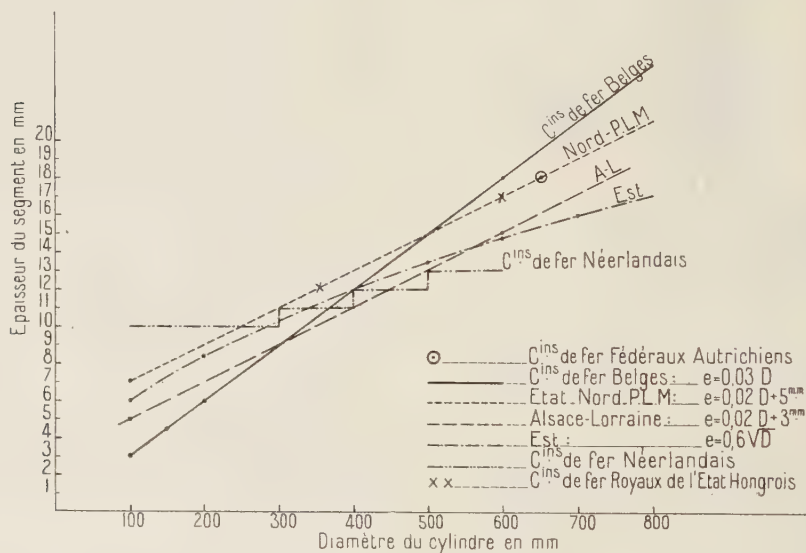


Fig. 10. — Thickness of piston rings.

Note: Epaisseur... = thickness of ring, in mm. — Diamètre... = cylinder diameter, in mm.

On modern or recently altered locomotives, there is a tendency to increase the number of rings and reduce their thickness, so as to increase the elasticity and reduce wear, whilst maintaining the same degree of tightness. The *French State Rys.*, for example, have increased the number of rings of the high-pressure pistons from 3 to 4, whilst reducing their width from 20 to 14 mm. (25/32" to 9/16"), and the number of rings on the low-pressure pistons from 2 to 3, their width being reduced from 25 to 16 mm. (63/64" to 5/8"). The *Est* and *P.O.-Midi Rys.* have also adopted 4 piston rings for the high-pressure pistons of their modern locomotives.

The *Reichsbahn* reports good results by replacing 3 standard 20 × 16 mm (25/32" × 5/8") rings by 4 or 5 rings of 16 × 8 mm. (5/8" × 5/16").

The influence of the elasticity of the rings on their wear has been demonstrated by the *P.L.M.* and by the *Royal Hungarian State Rys.*

On the former Railway, the high-pressure piston rings of the 4-6-2 engine with high superheat (380°C. = 716°F.) had to be renewed every 20 000 km (12 400 miles); after reducing the thickness and width and the initial clearance between piston and cylinder, the first tests showed that the gap was only 7 mm. (9/32") wide after running

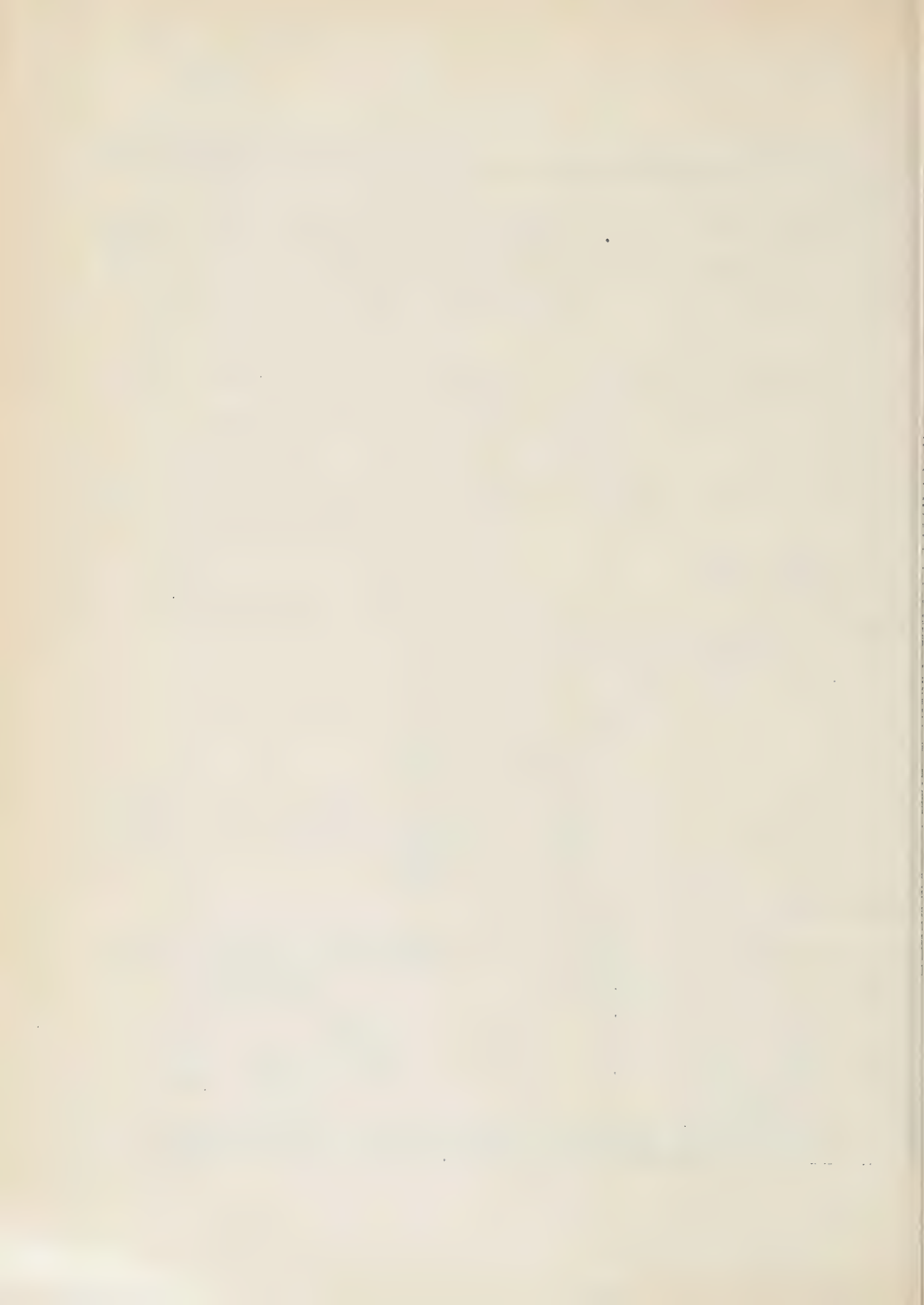
TABLE VII.

Characteristics and dimensions of piston rings.

ADMINISTRATIONS.	Shape of piston rings.	Dimensions of piston rings (1).		Joint.			Kind and characteristics of piston ring metal.	Number of rings per piston.	Life of piston packing rings.
		Thickness t (2) (mm.)	Width w (2) (mm.)	How split.	Gap.				
					Ring free. (mm.)	Ring in place. (mm.)			
<i>Deutsche Reichsbahn</i>	Rectangular, grooved.	16 for wide rings. 8 for narrow rings.	16 20	...	...	...	Cast iron.	Wide rings : 3. Narrow rings : 4 or 5 with tail rod.	50 000 to 60 000 km.
<i>Austrian Federal Rys.</i>	Square. Outside edges rounded off.	$t = 18$ for $D = 650$	$w = 18$ for $D = 650$	Obliquely.	...	...	Special perlitic cast iron, Brinell hardness > 190 .	3 with tail rod.	25 000 to 60 000 km. on express trains.
<i>Belgian Nat. Rys. Co.</i>	Rectangular. Outside edges rounded off to a 0.25 mm. radius .	$t = 0.03 D$	...	Straight.	...	0.5	Fine grained cast iron. Brinell hardness 190.	3 with tail rod.	90 000 km. on passenger trains.
<i>Alsace-Lorraine Rys.</i>	« Carels » rectangular.	$t = 0.002 D + 3$ $t_1 = t + 3$	$w = 20$. $w_1 = 24$.	Straight.	$0.05 D$ to $0.09 D$ varies with t	0.5	Vanadium-titanium perlitic cast iron.	3 or 4 with tail rod.	60 000 km. on express trains.
<i>Est Rys.</i>	...	$t + 0.6 \sqrt{D}$	...	Straight.	$0.00075 \frac{D^3}{w^3} + 1$	1	High-grade cast iron.	2, 3 or 4 with or without tail rod.	10 000 to 40 000 km. on fast locomotives. 20 000 to 35 000 km. on goods train locomotives.
<i>French State Rys.</i>	« Carels » rectangular grooved, with 6 release holes et equal distances.	$t = 0.02 D + 5$ $t_1 = 1.2 e$	$w_1 = 1.3 w$.	Straight.	0.07 D.	0.003 D.	Perlitic cast iron. Brinell hardness 196 to 210. Shear strength 27 kgr./mm ² .	2, 3 or 4 with or without tail rod.	HP : 30 000 to 45 000 km. LP : 45 000 to 90 000 km.
<i>Nord Rys.</i>	« Carels » rectangular.	$t = 0.02 D + 5$	...	Straight.	0.08 D.	»	S.T.U. No. 70 cast iron.	2 or 3 with tail rod.	20 000 to 40 000 km.
<i>P.L.M. Rys.</i>	Rectangular with or without groove. Outside edges rounded off to 2 mm. radius.	$t = 0.02 D + 5$	...	Obliquely.	0.08 D.	1 if $D < 400$ 1.5 if $400 < D < 580$ 2 if $580 < D < 720$...	Vanadium-titanium cast iron.	2 or 3 with tail rod.	27 500 to 47 500 km.
<i>P.O.-Midi Rys.</i>	Rectangular. Piston ring groove varying with the width; 3-mm. release holes. Outside edges rounded off to a 0.5 or 1 mm. radius.	t fixed by tables $t_1 = t + 3$ if $D < 600$ $t_1 = t + 4$ if $D > 600$	$w =$ found by tables. $w_1 = 1.5 w$. w_1 max. = 40.	Straight.	0.07 D.	...	Special perlitic cast iron.	3 or 4 with tail rod.	50 000 km.
<i>Algerian Rys.</i>	The same shape as on the P.L.M. Rys.	$t = 0.02 D + 5$	...	Obliquely.	0.08 D.	As on P.L.M. Rys.	...	...	15 000 to 25 000 km.
<i>Hungarian State Rys.</i>	Rectangular. Outside edges rounded off to a 3-mm. radius.	t calculated to give a specific pressure of between 0.2 and 0.8 kgr./cm ² . ($t = 12$ when $D = 355$, and $t = 17$ when $D = 600$.)	$w = 13$ for $D = 355$. $w = 20$ for $D = 600$.	Obliquely.	0.10 to 0.20 D	3	Ordinary cast iron with sufficient Si content for elasticity. Hardness 10 % below that of cylinder.	3 with tail rod.	40 000 to 50 000 km.
<i>Netherlands Rys.</i>	Rectangular.	$D < 301$ $t = 10$ $301 < D < 400$ $t = 11$ $400 < D < 500$ $t = 12$ $500 < D < 600$ $t = 13$	...	...	...	...	...	3 with tail rod.	30 000 km.

(1) D = cylinder diameter, in mm.

(2) Letters without index indicate original dimensions; letters with index indicate limiting dimensions.



45 000 km. (28 000 miles) with the modified rings, whereas the gap was 15 mm. (19/32") at the end of 20 000 km. (12 400 miles) with the old design.

The *Royal Hungarian State Rys.* usually use rings designed to give a pressure of 0.4 to 0.8 kgr./cm² (5.69 to 11.38 lb. per sq. in.) on the cylinders, but have recently carried out tests with the pressure reduced to between 0.2 and 0.3 kgr./cm² (2.84 and 4.27 lb. per sq. in.); this pressure is considered sufficient and reduces appreciably the wear of the cylinders and rings.

(b) *Material used for rings.*

The rings are usually of mild or perlitic cast iron with a Brinell hardness of about 190; the *P.L.M. Rys.* use vanadium-titanium cast iron.

(c) *Methods of machining the rings.*

By using rings of uniform thickness, an endeavour is made to fulfil the two following conditions:

- the ring when in place is cylindrical;
- the ring exerts a uniform pressure on the cylinder walls.

These two conditions are realised, although imperfectly, by one or other of the two following methods:

1. the elasticity is given after machining by a special tensioning machine (*Belgian Rys.*) or by simple extension, or by hammering;

2. the elasticity is obtained by the amount of gap when free.

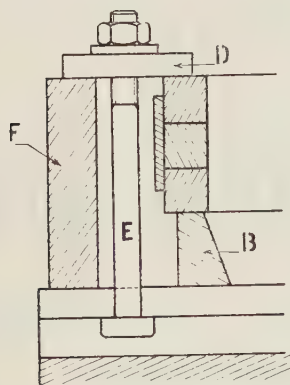
As a rule the gap is proportional to the diameter of the cylinder, and does not take the thickness of the ring into account, as this varies with the state of wear of the cylinder.

In all cases the ring is machined after being closed in by a collar, special precautions being taken to prevent the rings being deformed by the jaws holding them during machining.

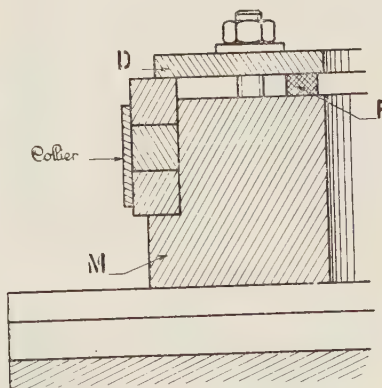
With this object, the *P.L.M. Rys.* first of all machine the inside faces of the rings, and then turn the outside face by holding the rings on the inside on a mandrel turned to the exact size (fig. 11).

(d) *Life of rings.*

Table VII gives the average distances covered between renewals of rings on



Machining inside faces.



Machining outside faces (the collar is removed after the bolt is tightened).

Fig. 11. — *P.L.M.* method of machining piston rings.

Note: D and E: flange and fixing bolt, — B and F: distance pieces. — M: wood mandril.

the different railways; no conclusions can be drawn from them, owing to the very considerable variations due to the different services worked and varying conditions under which the rings are withdrawn, on the different Railways.

IV. — Piston rod and valve spindle packings.

On recent locomotives with high boiler pressure and high superheat, most of the railways use piston rod and valve spindle packings consisting of a number of metal segments.

The metals used for making these

segments are of many kinds (mild cast iron, F.S.I. high-grade cast iron, electrolytic copper, etc.)

White metal with its rather low fusing point is found only on locomotives with low or moderate superheat.

The packings used differ sometimes from the original type already described in the reports to the 1930 Congress; this remark applies to the packings used on the *Reichsbahn* and also the *Garex* packings.

In the case of the *Reichsbahn* packing (fig. 12), each stuffing box contains two segments: one known as the sealing segment in 4 parts, and the other as the covering segment in 2 parts. All these segments are assembled together by garter spring.

In the case of the modified T type *Garex* used on the *P.L.M. Rys.* (fig. 13) the stuffing boxes containing the segments are bolted together to make easy to take the packing apart.

V. — Summary.

1. The superheat temperature corresponding to maximum efficiency of the locomotive is about 400°C. (752°F.) on locomotives with a boiler pressure of 16 kgr./cm² (228 lb. per sq. in.). It should exceed 400°C. on locomotives with higher boiler pressures, not fitted with intermediate steam preheaters, but the temperature is very soon limited by the difficulties of lubrication and by the failure of the metals to stand high temperatures.

2. Flue tube superheaters with divided headers are used almost generally. Special elements are often used to give high superheat temperatures.

3. Mechanical lubricators and piston rod and valve spindle packings with multiple metal segments are now usual practice on modern locomotives.

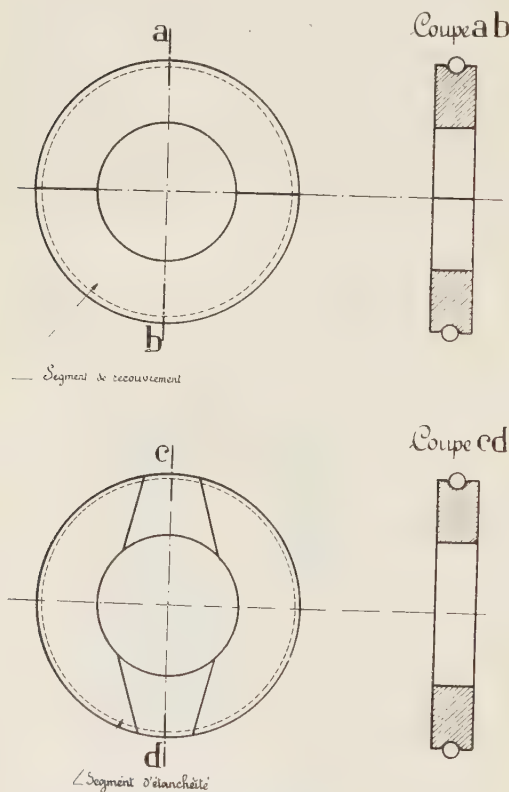


Fig. 12: — *Reichsbahn* packing rings.

Note: Segment de recouvrement = covering ring, — Segment d'étanchéité = steam-tight ring.

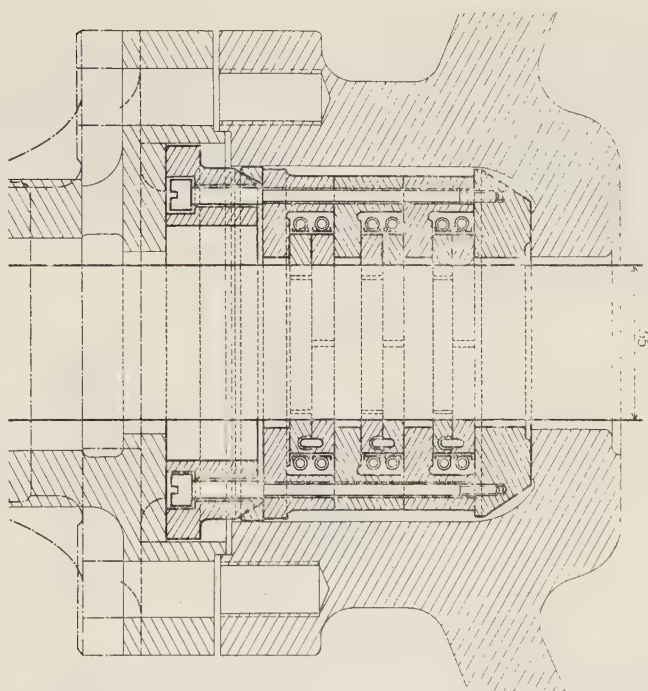


Fig. 13. — *Garex* type T packing.

CHAPTER V.

Feed water preheating.

I. — Preheating by cylinder exhaust steam.

1. Equipment used.

Table VIII shows for each Railway the number and type of feed water heaters fitted on line locomotives.

This table shows the considerable increase in the use of these equipments on some Railways; in particular they are provided on all new or rebuilt engines.

If feed water heaters tend more and more to replace the ordinary injectors, despite the simplicity of the latter, this is because they not only show savings in fuel and water, but they also increase the power of the locomotives, reduce the

work to be done by the firemen, and improve the life of the firebox, all essential things in modern heavily worked locomotives.

Most of the feed water heaters used are of well known types, which have been described on many occasions; consequently we shall limit ourselves to giving details of new types and of improvements to the old types, to make them more efficient.

(a) *Heinl* (1) feed water heater.

The *Heinl* feed water heater has been adopted by the *Austrian Federal Rys.*

It mainly consists of :

— two direct contact condensers, one

(5) Cf. LEHNER, *Organ für die Fortschritte des Eisenbahnwesens*, 1st June 1932, page 221.

low-pressure in which the water is heated by the exhaust steam from the cylinders, and the other high-pressure, heated by the exhaust steam from the water pump;

— a steam engine in tandem with a two-cylinder pump, one of which cylin-

ders pumps cold and hot water from the low-pressure condenser, and the other (double-acting) cylinder deals with hot water from the high-pressure condenser.

The *Heinl* feed water heater can be completed by an economiser. Figure 14 is a diagram of the equipment of the

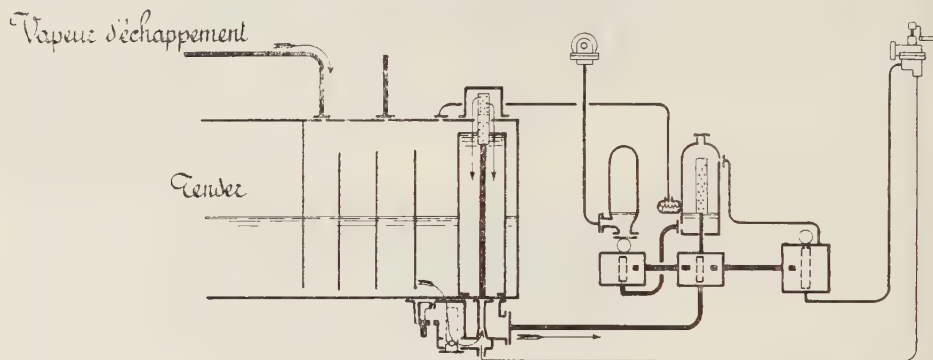


Fig. 14. — Diagram of the *Heinl* feed water heater.

Note: Vapeur d'échappement = exhaust steam.

4-6-4 (class 729) suburban tank engines. The combined cold and hot water cylinder of the usual equipment has been replaced in this case by a double-acting hot water cylinder. One of the water tanks is divided into compartments. The first condensation takes place in one of the compartments; an auxiliary steam injector maintains the water at a constant level in another compartment from which the hot water is pumped.

Feed water temperatures of about 115°C. (239°F.) have been recorded with the *Heinl* feed water heater.

(b) *A.C.F.I. RM-Integral* type feed water heaters.

Several improvements have been introduced in the *A.C.F.I. RM-Integral* type feed water heater. Amongst these are the level and feed regulators.

(α) The level regulator regulates the admission of cold water to the condenser in accordance with the water level in

the degasing chamber (fig. 15). The installation is simplified by this means as there is less pipework.

(β) The *feed regulator* regulates the oscillating discharge from the cold water pump. It consists of a small cylinder inside which there is a piston, one side of which communicates with the delivery side of the cold water pump and the other with the exhaust steam from the cylinder controlling this pump. At each stroke part of the water to be pumped is stored in the feed regulator, to be released at the end of the stroke.

By regulating the feed, the condensation and consequently the exhaust pressure are regulated at the same time.

2. Tests carried out and results obtained.

The comparative tests carried out by the *Deutsche Reichsbahn* show that the *Knorr* feed water heater shows a slightly greater economy than that given by the *Friedman* injector.

TABLE VIII.

Position, in 1936, of the different Administrations as regards feed water preheating.

Type of apparatus used.			Germany.	Austria.	Belgium.	Finland.	France, Colonies and Protectorates.							Hungary.	Netherlands	Poland.	
			Deutsche Reichsbahn.	Federal Rys.	Nat. Rys. Co.	State.	Alsace-Lorraine.	Est.	State.	Nord.	P.L.M.-	P.O.-Midi.	Algerian State Rys.	Hamah and Extensions.	State.	lands. Rys.	State.
Exhaust steam injectors.	Metcalf	F	...	...	727	...	11	227	...	...	...	198	...	...	73	...	
		H-HP	...	...		...			...	...	...	...	...	...			
		Friedmann.	...	...		...			184	...	...	...	...	...		...	383
	Total		...	...	727	184	11	227	42	...	...	198	...	...	383	73	...
Exhaust steam feed water heaters.	surface open	A.C.F.I. R.S.	...	...	...	...	...	...	4	...	...	...	...	...	...	...	...
		Knorr	15 000	...	...	93	587	...	...	...	...	71	...	...	118	712	...
		Teudloff-Dittrich	...	...	...	...	...	...	...	...	...	...	...	...	52	...	...
	Total		15 000	...	...	93	587	...	4	...	...	71	...	...	170	712	...
closed	Heinl.	...	30	...	...	...	...	...	...	...	...	...	...	...	...	...	...
	Worthington	A - BZ	...	...	...	4	...	33	10	...	5	...	...	...	...	...	...
		AX	...	...	...	...	...	51	...	...	35	...	...	2	...	...	...
	A.C.F.I.	RM, ordinary	...	...	553	...	325	77	440	...	57	228	29	...	...	...	...
		RM, Integral	...	...	...	...	10	...	19	...	48	...	...	...	...	...	...
	Dabeg	...	750	...	...	...	...	4	147	...	406	25	58	...	...	...	...
Total		...	780	553	4	335	114	667	631	1 055	170	380	29	2	...	...	
Economiser working on heat recovered from combustion gases.	Dabeg	...	...	...	...	...	...	...	...	80	...	...	...	...	...	...	...
Total number of locomotives equipped			15 000	780	1 280	281	933	341	713	731	1 135	439	380	29	555	785	...
Number of line locomotives of the Railway.			22 500	1 900	3 037	676	1 095	1 950	2 947	...	4 800	2 648	714	44	1 614	846	...
Percentage of locomotives equipped			66.6	41	42.1	41.6	85.2	17.4	24.2	...	25.7	16.5	53.2	65.9	34.3	92.8	...

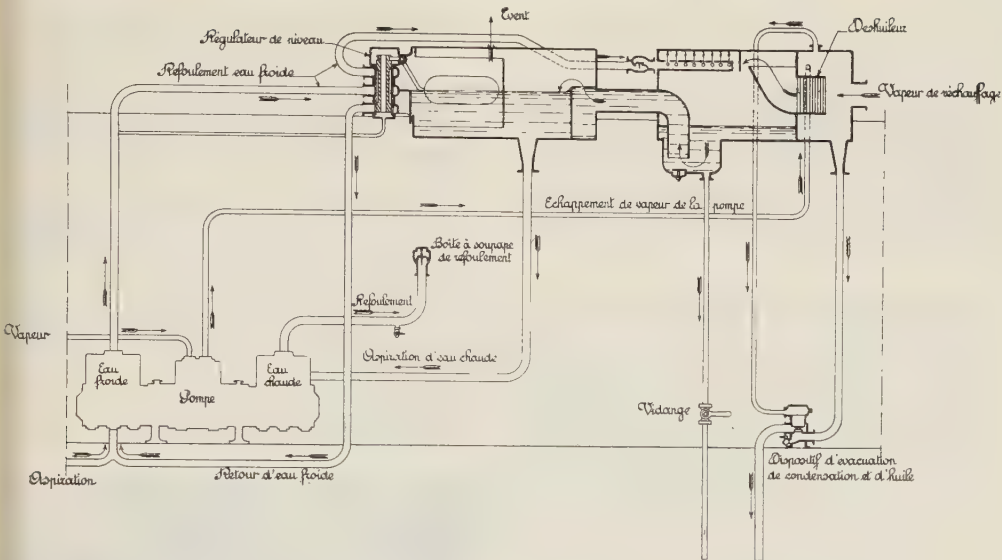


Fig. 15. — A.C.F.I. type R.M. integral feed water heater with level regulator.

Explanation of French terms :

Aspiration d'eau chaude = hot water suction. — Boîte... refoulement = clack box. — Déshuileur = de-oiler. — Dispositif... d'huile = device for draining away the condensate and oil. — Echappement de vapeur de la pompe = exhaust steam from pump. — Eau chaude = hot water. — Eau froide = cold water. — Event = vent. — Pompe = pump. — Refoulement = delivery. — Refoulement eau froide = cold water delivery. — Régulateur de niveau = level regulator. — Retour d'eau froide = cold water return. — Vapeur = steam. — Vapeur de réchauffage = steam to heater. — Vidange = drain cock.

Comparative tests carried out on the *Est* Railway by the constant speed method with different types of feed water heating equipment gave the following results :

Type of heater	Water saving	Fuel saving.
Davies & Metcalfe injector	10 %	8.8 %
RM type A.C.F.I. heater	12.5 to 16.5 %	10 to 11 %
Worthington heater	12.8 %	9.3 %
Dabeg heater	10 to 12 %	Not ascertained.

It should be noted that the saving obtained during trials at constant speed only relate to the coal consumed under constant working conditions and are therefore higher than those found in ordinary working.

The *Belgian National Rys. Co.* state that on a suburban locomotive, the Da-

vies & Metcalfe automatic type No. H. 7 exhaust steam injector gave a fuel saving of 4 %.

On the *P.O.-Midi Rys.* with the A.C.F.I. RM-Integral feed water heater, fitted to 4-6-2 and 4-8-0 engines, feed water temperatures of from 100 to 110° (232 to 250°F) are obtained at hourly rates of

13 m³ (636 cu. ft), with a fuel economy of 8 %.

The *Algerian Rys.*, with a high-pressure Worthington heater have obtained temperatures of 105 to 140°C. (241 to 284°F.) and a 12.04 % saving of fuel; a heater of the same type was found to save 10 % fuel on the *Hungarian State Rys.*

3. Amortization and maintenance costs.

The figures supplied as regards maintenance costs cannot be compared owing to the difference in the economic conditions and the estimating methods; the information communicated to us as regards the period of amortization is given below without comment :

— Exhaust steam injectors :

The amortization period is 8 years on the *Belgian Nat. Rys. Co.*, and 3 1/2 years on the *Hungarian State Rys.*

— Feed water heaters.

The amortization period is :

Austrian Federal Rys.	2 to 3 years.
Belgian Rys.	9 years.
Alsace-Lorraine Rys.	3 to 6 years.
French State Rys.	5 to 6 years.
Est Rys.	10 years.
Hungarian State Rys.	5 to 11 1/2
years according to the type of locomotive.	

4. Effects of feed heating on the superheat temperature.

The whole of the Railways agree that, all other things being equal, the use of feed water heaters, by reducing the rate of combustion, lowers the superheat temperature.

This reduction is about 20°C. (36°F.) on the *Nord Ry.* and 15 to 18°C. (27 to 32.4°F.) on the *P.O.-Midi Rys.*

To restore the superheat temperature to its original value, the simplest method is to reduce the diameter of the blast pipe top by 12 to 15 %.

II. — Feed heating by the combustion gases.

The *P.L.M. Rys.* report using the *Dabeg economiser*, the tests of which were mentioned in the report to the Madrid Congress.

The economiser is mounted in series with the exhaust steam feed water heater.

The arrangement uses mixed elements with headers with 6 outlets. Figure 16 illustrates the design, which has been made to take up as little space as possible in the smoke box.

The economiser elements are :

— washed out whilst running every

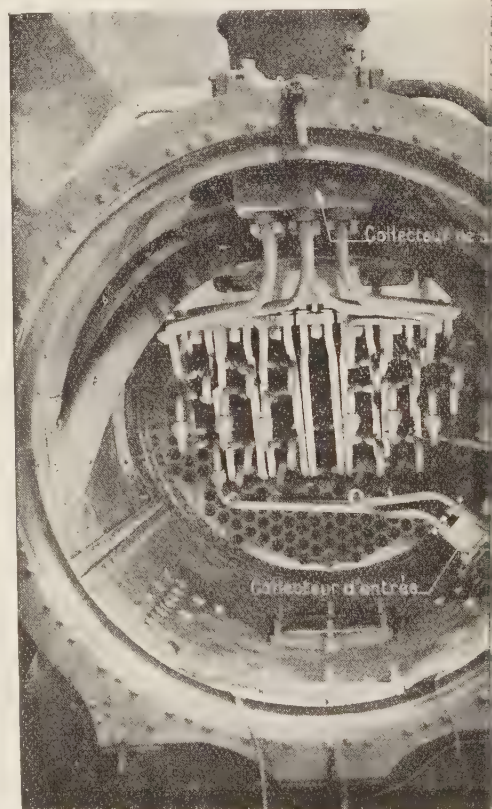


Fig. 16. — *Dabeg* economiser fitted to a *P.L.*

Note: Collecteur de sortie (d'entrée) = outgoing (inlet)

day by means of a special device (blow-down controlled from the cab) ;

— descaled in the sheds, at intervals, by passing acidulated water through them (1).

Thanks to the economiser the feed water temperature is raised to 130°C. (286°F.) before it is introduced into the boiler.

The 1930 report mentioned a reduction of 20°C. (36°F.) in the superheat temperature, attributable to this apparatus. This difficulty has been overcome by using the 5P-4 superheater (see Chapter IV), the elements of which, whilst they allow the economiser to be fitted in the superheater tubes (fig. 17) increase the superheat temperature by 25° C.

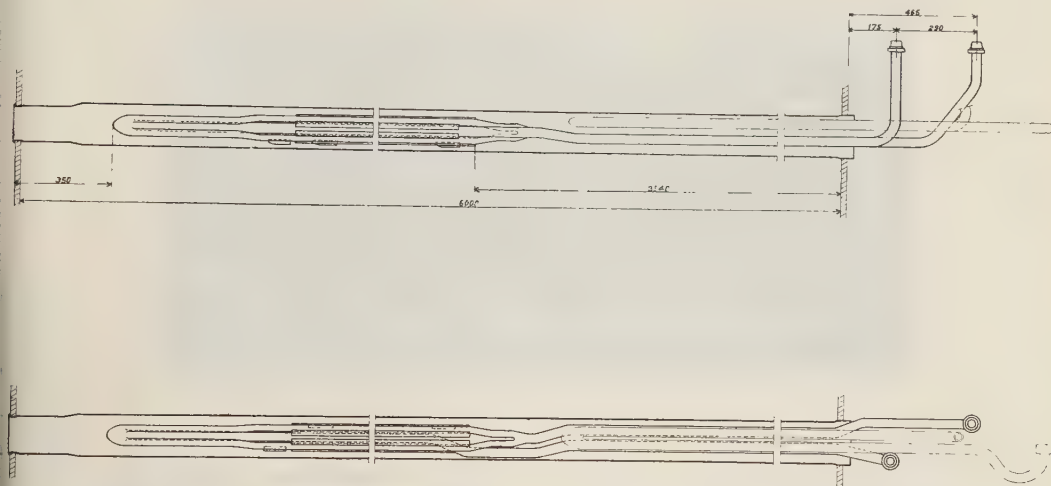


Fig. 17. — Type 5 P 4 superheater element fitted in conjunction with a *Dabeg* economiser element.

(45°F.) relatively to that given with *Schmidt* elements.

The *Dabeg* economiser is fitted on all the 4-6-2-F locomotives, and will be fitted to all the 4-6-2-H locomotives of the *P.L.M. Rys.*

III. — Summary.

1. All modern locomotives are now equipped with feed water heaters, or when simplicity is particularly desired, with exhaust steam injectors.

2. Most of the railways prefer the closed type of feed water heaters.

3. Pumps mechanically driven off the motion of the locomotive are liked owing to their simplicity, so long as the running speed is not too high for their proper working.

4. Steam-driven pumps are more costly but are more easily fitted : they are the most widely used.

5. Economisers mounted in series with the cylinder exhaust steam heaters are capable of giving valuable results.

(1) The use of an anti-scaling compound should make it possible to suppress or at least lengthen the periods between washing out and descaling the economisers. A trial is in hand on the *P.L.M. Rys.* and so far has given entirely satisfactory results.

CHAPTER VI.

Air preheating.

Only one Administration, the *Austrian Federal Rys.*, has used for trial purposes on a goods engine of the 0-10-0, class 80, type an air preheater by means of the combustion gases (fig. 18.)

The resulting increase in weight was 4.2 tons or 6.79 %.

The saving in fuel was insignificant. The arrangement will not be extended.

* * *



Fig. 18.— Austrian locomotive equipped with an air preheater.

CHAPTER VII.

Improved blast pipe design.**I. — Present position.**

Tables IX and X show the main characteristics of the exhausts and the engines on which they are fitted.

With very few exceptions all the railways have endeavoured to improve the draught on their locomotives, either by using new types of exhausts or by improving existing types.

The improvements have been in connection with :

— the characteristics of the exhaust, (large blast pipe tops — multiple blast pipe tops — double chimneys).

— equalising the draught over the grate (obtaining the best position of the upper plane of the fixed blast pipe top — fitting petticoats).

II. — New types of blast pipe and improvements to old designs.**1. Kylchap fixed blast pipe.**

The *P.O.-Midi* has improved the efficiency of the 1K/1C Kylchap blast pipe by a more scientific design of breeches pipe (fig. 19).

Fig. 20 shows the dimensions of the blast pipe on the 240.700 class 4-8-0 locomotives.

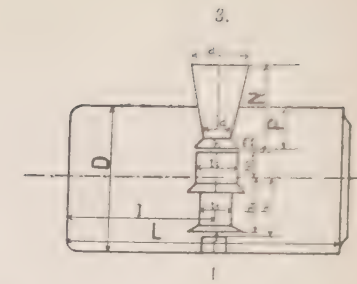
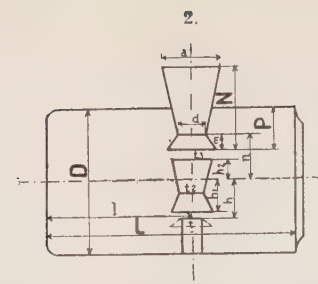
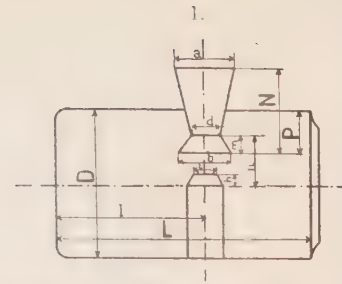
This blast pipe has made it possible to burn coal at the rate of 1200 kgr/m² (245 lb. per sq. ft.) on a grate of 3.76 (40.4 sq. ft.) with a draught of 550 mm (21.6") of water, and a pressure 750 gr./cm² (10.7 lb. per sq. in.)

2. P. L. M. variable blast pipe with petticoats and cross bars.

After various tests to improve P.L.M. clover-leaf blast pipe by

TABLE IX.

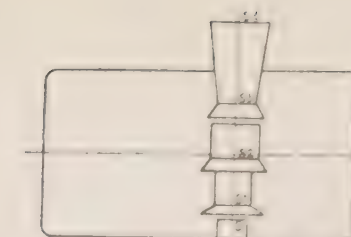
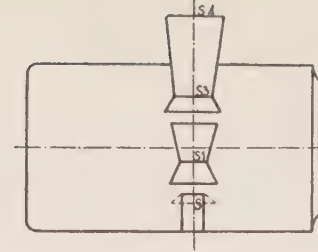
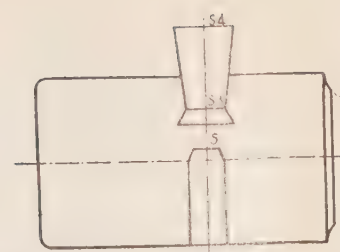
Leading dimensions of the blast pipes (1).



ADMINISTRATIONS.	Type of blast pipe : F = Fixed. V = Variable. SV = Semi- or partly variable.	Locomotives equipped.		Sketch.	Smoke-box dimensions.		Diameter and position of exhaust nozzles.			Diameter and position of petticoats and intermediate exhaust nozzles.					Dimensions and position of chimney.							REMARKS.		
		Class.	Type.		D	L	t	l	h (2)	t ₁	t ₂	t ₃	h ₁ (2)	h ₂ (2)	h ₃ (2)	a	b	d	m	n	N		V	
Deutsche Reichsbahn	Ordinary	F	Class 03	4-6-2	1	1 872	2 564	144	1 234	-619	...	...	...	...	...	...	590	510	...	...	531	...	...	(1) All dimensions are given in mm. (2) The sign — in front of the dimensions h, h ₁ , h ₂ or h ₃ means that the dimension is to be read, relatively to the centre line, in the opposite direction to that shown on the sketch.
Austrian Federal Rys.	Kylchap	F	Class 214	2-8-4	2	2 228	2 740	160	1 680	795	376	280	338	650	-65	...	614	652	460	275	280	1 245	201	...
	Filip.	F	Class R 729	4-6-4	3	...	1 900	135	...	...	245	320	...	...	...	...	476	600	420	...	...	1 000	...	...
Belgian National Rys. Co.	Ordinary simple with petticoat	F	Type 9	4-6-0	3	1 796	1 650	150	750	340	238	310	...	260	-220	510	450	535	450	162	750	870	...	...
	Ordinary double with petticoat	F	Type 35	2-8-0	1	2 206	2 008	2 × 130	1 168	-325	...	...	...	...	...	...	2 × 420	1 160	2 × 420	110	668	772	561	...
	Lemaître, 6 nozzles	SV	Type 9	4-6-0	2	1 820	...	5 × 63	750	{ F-310	570	475	475	-385	635	...	600	650	565	85	700	745	201	...
	Kylchap.	F	Type 9	4-6-0	3	1 820	...	1 × 60	...	{ V-210	280	370	...	128	...	478	540	490	460	360	913	910	349	...
Alsace-Lorraine Rys.	Kylchap, double	F	S.16	4-6-2	3	1 887	2 678	2 × 132	1 678	330	2 × 275	2 × 340	...	330	-105	505	2 × 500	2 × 480	2 × 420	260	830	760	375	...
	Kylchap, 1 K/1 C	F	G.12	2-10-0	3	...	...	168	...	500	300	400	...	500	70	355	560	520	480	320	675	880	565	...
	Modified clover leaf	V	S.14	...	1	...	2 155	220	1 513	-294	...	...	...	...	...	...	560	710	510	140	520	1 050	458	...
Est Rys.	Clover leaf, wide section without petticoat	V	241 001 to 041	4-8-2	1	1 762	2 241	252	1 339	-23	...	...	...	...	...	...	600	580	500	150	377	1 095	654	...
	Clover leaf, wide section without petticoat	V	231 001 to 040	4-6-2	1	1 680	2 154	252	1 180	33	...	...	...	...	...	...	620	580	500	150	293	1 176	604	...
	Duchatel, double without petticoat	F	230 200	4-6-0	1	1 550	2 100	...	1 330	90	...	...	...	...	...	...	...	...	...	200	450	...	...	...
French State Rys.	Kylchap, 1 K 1 C	F	231 501 to 783	4-6-2	2	1 680	2 532	170	1 555	254	465	312	312	234	198	...	575	500	440	444	650	826	646	...
	Kylchap, 2 K/2 C	F	231 501 to 783	4-6-2	3	1 680	...	2 × 118	...	270	2 × 260	2 × 320	...	258	250	650	2 × 470	2 × 450	2 × 403	250	958	710	132	...
	Lemaître	SV	231 501 to 783	4-6-2	1	1 680	...	F 5 × 60	...	{ F-16	...	...	...	...	...	...	680	610	440	450	650	1 220	639	...
Nord Ry.	Lemaître, type XI	SV	3 1200	4-6-2	1	1 804	...	V 1 × 118	...	{ V-165	...	...	...	...	...	...	674	604	544	450	640	1 220	711	...
	Lemaître, type XI	SV	3 1200	4-6-2	1	1 804	...	F 5 × 60	...	{ F 15	...	...	...	...	...	...	674	604	544	450	640	1 220	711	...
P.L.M. Rys.	231 G	F	231 G	4-6-2	2	1 718	2 500	2 × 160	1 620	250	2 × 380	2 × 275	2 × 275	150	265	...	2 × 440	2 × 420	2 × 330	295	600	1 048	554	...
	241 C-1	F	241 C-1	4-8-2	2	1 815	...	2 × 175	...	250	2 × 414	2 × 300	2 × 300	150	320	...	2 × 475	2 × 460	2 × 360	255	600	955	...	...
	P.L.M., double with cross bars and petticoats	V	151 A	2-10-2	2	1 815	3 000	2 × 190	2 105.5	250	2 × 450	2 × 328	2 × 328	150	320	...	2 × 520	2 × 500	2 × 394	255	625	955	537.5	...
	151 A	V	151 A	2-10-2	2	1 815	...	2 × 190	...	250	2 × 450	2 × 328	2 × 328	150	320	...	2 × 495	2 × 485	2 × 394	255	625	955	537.5	...
	241 D	F	241 D	4-8-2	2	1 815	...	2 × 190	...	250	2 × 450	2 × 328	2 × 328	150	320	...	2 × 495	2 × 485	2 × 394	255	625	955	537.5	...
P.O.-Midi Rys.	141 C	F	141 C	2-8-2	2	1 718	...	2 × 175	...	250	2 × 414	2 × 300	2 × 300	150	265	...	2 × 460	2 × 450	2 × 360	295	600	1 048	554	...
	Kylchap double, 1K 1 C 2nd type	F	240 701 to 713	4-8-2	3	1 684	2 465	2 × 120	...	292	2 × 257	2 × 320	...	339	-175	670	2 × 470	2 × 460	2 × 403	...	...	725	165	...
	Kylchap double, 1 K 1 C 1st type	F	231 701 to 731	4-6-2	3	1 680	2 555	2 × 123	1 515	292	2 × 257	2 × 320	...	339	-175	670	2 × 470	2 × 460	2 × 403	...	...	725	165	...
Algerian Rys.	P.L.M., double, with cross bars and petticoats	V	231 132 AT	Garratt	2	2 188	1 713	2 × 186	1 094	0	2 × 420	2 × 300	2 × 300	-100	-200	520	2 × 470	2 × 460	2 × 380	320	890	800	524	Arranged side by side, transversely.
	Ordinary	F	424	4-8-0	1	1 772	2 400	140	1 330	-566	...	...	...	...	...	...	530	615	455	100	500	850	386	...
Hungarian State Rys.	Ordinary	F	402	...	1	1 772	2 400	140	1 330	-516	...	...	...	...	...	...	530	615	455	100	650	...	236	...
	Ordinary	F	402	...	1	1 772	2 400	140	1 330	-516	...	...	...	...	...	...	530	615	455	100	650	...	236	...

TABLE X.

Characteristic ratios of blast pipes (1).



ADMINISTRATIONS.	Class of engines.	Type of blast pipe.	Grate area (m ²) G	Total heating surface (m ²) C	Total volume of LP cylinders (compound loc.), and HP (S.E. loc.) (litres) V	Total cross sectional area, in cm ² , of :					Ratios.						REMARKS
						Blast pipe top. S	First intermediate nozzles. S ₁	Second intermediate nozzles. S ₂	Chimney, at the waist. S ₃	Chimney, at the top. S ₄	$\frac{S}{V}$ (cm ² /litres).	$\frac{S}{C} \times 10^3$	$\frac{S_1}{S}$	$\frac{S_2}{S}$	$\frac{S_3}{S}$	$\frac{S_4}{S}$	
<i>Deutsche Reichsbahn</i>	03	Ordinary, simple.	4.05	212.22	374	163	...	...	...	2 740	0.436	...	...	...	...	16.8	
<i>Austrian Imperial Rys.</i>	214	Kylälä.	4.72	222	478	200	615	...	1 662	2 970	0.418	0.763	3.075	...	8.31	14.85	
	R 729	Filip.	3.55	171.3	282	143	473	805	1 390	1 780	0.507	0.835	3.307	5.029	6.72	12.45	
<i>Belgian Imperial Rys. Co.</i> . . .	Type 9	Ordinary, simple.	3.13	211	...	177	445	755	1 590	1 590	...	0.827	2.514	4.265	8.28	8.28	
	Type 35.	Ordinary, double.	...	214	...	265	...	...	2 771	2 771	...	1.238	...	...	10.40	10.40	
	Type 9	Lemaître, 6 nozzles.	3.13	214	...	150 to 243	...	...	2 325	3 567	...	0.701/1.135	...	...	15.5/9.57	23.78/14.68	
	Type 9	Kylchap.	3.13	214	...	221	615	1 075	1 662	2 290	...	1.033	2.783	4.864	7.52	10.36	
<i>Alsace-Lorraine Rys.</i>	S 16	Kylchap, double.	4.50	223.7	374	215	712	1 820	2 770	3 927	0.575	0.961	3.311	8.465	12.88	18.26	
	G 12	Kylchap, 1 K/1 C.	3.90	194.9	505	182	424	1 260	1 810	2 463	0.360	0.934	2.330	6.923	9.95	13.53	
	S 14	Modified clover-leaf.	4.27	211.97	417	...	...	...	...	...	...	...	...	...	...	...	
	G 81	Kylchap.	...	144.4	373	167	356	1 050	1 640	...	0.417	1.156	2.132	6.287	9.82	...	
	S 14	Kylchap.	4.27	211.97	417	164	458	1 820	1 520	...	0.393	0.774	2.793	9.27	...	...	
	G 16	Kylchap, double, variable.	5.00	245.19	561	180 to 304	738	1 560	3 240	...	0.321/0.542	0.734/1.240	4.10/2.428	8.660/5.101	18.07/10.66	...	
<i>Est Rys.</i>	241-000	Clover leaf, of wide section.	4.43	223.20	492	238	...	...	1 963	2 827	0.484	1.066	...	...	8.25	11.88	
	231-000	»	4.27	211.68	418	238	...	...	1 963	3 019	0.569	1.124	...	...	8.25	12.68	
	230-200	»	3.16	135.48	372	129/211	...	...	1 963	...	0.567	1.557	...	...	9.30	...	
	230-200	Duchatel.	3.16	135.48	372	188.5	...	...	1 721	...	0.504	...	...	...	9.15	...	
	150-000	Clover leaf, of wide section.	3.25	203.26	486	211	...	...	1 963	...	0.434	1.038	...	...	9.30	...	
	141-700	»	2.80	139.63	404	236	...	...	1 933	...	0.584	1.690	...	...	8.19	...	
<i>French State Rys.</i>	231-500	Kylchap, 1 K/1 T.	...	...	...	227	764	764	1 520	2 596	...	...	3.366	3.266	6.70	11.44	
	231-500	Kylchap, 2 K/2 C.	...	...	...	219	619	1 608	2 551	3 470	...	...	2.826	7.342	11.05	16.84	
	231-500	Lemaître.	...	...	...	141 to 250	...	...	1 520	3 631	...	...	...	...	10.78/6.08	25.75/14.32	
<i>Nord Ry.</i>	3-1 200	Lemaître, type X 1.	3.48	195.98	416	154/252	...	...	2 324	3 567	0.370/0.606	0.786/1.286	...	...	13.09/9.22	28.16/14.16	
	231 G	P.L.M., double with cross bars.	4.25	206.25	430	181/274	1 188	...	1 711	3 041	0.421/0.637	0.877/1.328	6.563/4.336	...	9.45/6.24	16.89/11.10	
<i>P.L.M. Rys.</i>	241 C	»	5.006	248	508	217/328	1 412	...	2 036	3 544	0.427/0.646	0.875/1.322	6.511/4.308	...	9.38/6.21	16.33/10.80	
	151 A	»	5.00	243.77	610	217/328	1 690	...	2 438	4 247	0.356/0.538	0.890/1.345	7.888/5.152	...	11.23/7.43	19.57/12.95	
	241 D	»	5.00	246.16	570	242/366	1 690	...	2 438	3 849	0.424/0.642	0.983/1.487	6.983/4.617	...	10.07/6.66	15.90/10.51	
	141 C	»	4.25	206.25	570	200/302	1 412	...	2 036	3 324	0.351/0.530	0.970/1.464	7.065/4.679	...	10.18/6.74	16.62/11.00	
<i>P.O.-Midi Rys.</i>	240-701 to 713	Kylchap, double, 2nd type.	3.76	213.61	418	200	1 037	1 608	2 551	3 470	0.478	0.936	5.185	8.590	12.75	17.35	
	231-701 to 721	Kylchap, double, 2nd type.	4.27	184.71	418	177.5	1 037	1 608	2 551	3 470	0.425	0.061	5.842	9.059	14.37	19.55	
<i>Algerian Rys.</i>	231-132 AT 1	P.L.M., double with cross bars.	5.07	259.6	512.72	251/400	1 412	...	2 268	3 470	0.489/0.780	0.967/1.541	5.625/3.530	...	2.03/5.67	13.82/8.67	
<i>Hungarian State Rys.</i>	424	Ordinary.	4.45	220.50	374	132	...	...	1 626	2 206	0.354	1.674	...	...	12.32	16.71	
	402	»	...	...	...	132	...	...	1 626	2 206	...	...	...	...	12.32	16.71	

(1) In the case of variable blast pipes, two ratios are given, one with the blast pipe throttled, and the other with the blast pipe released.

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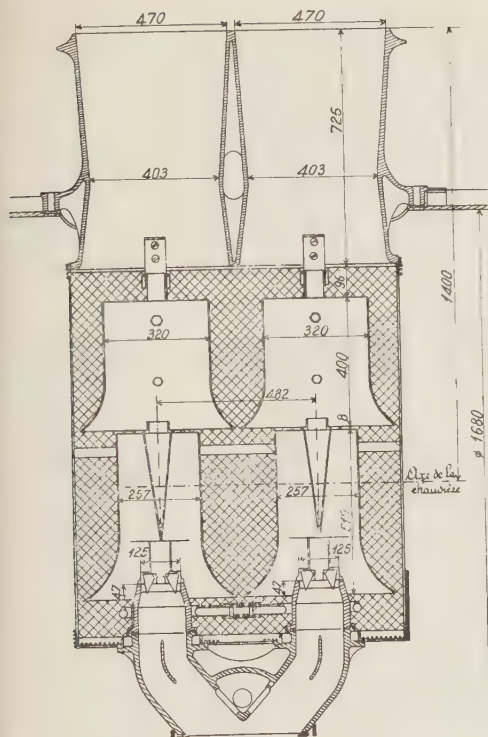


Fig. 19. — IK/IC *Kylchap* double blast pipe.

Note: Axe de la chaudière = centre line of boiler.

creasing the number of wings of the moveable part (3, 4 or 6) and the number (0, 1 or 2) of petticoats, the *P.L.M.* *Rys.* have fitted on their new or rebuilt locomotives, a new type of *P.L.M.* blast pipe using a petticoat and a single or double cross bar. Figure 21 shows this blast pipe as fitted on the 2-10-2-A locomotives of the *P.L.M.* and figure 22 gives some of its features.

During a test at constant speed, the *P.L.M.* blast pipe enabled a drawbar horse-power of 3 000 to be maintained whilst burning over 700 kgr./m² (143 lb. per sq. ft.) of fuel on a 5-m² (53.8 sq. ft.) grate, with a draught of 210 mm. (8.27") of water, and a back pressure of 330 gr./cm² (4.69 lb. per sq. in.).

The *Algerian Rys.* have fitted their *Garratt* locomotives with the double *P.L.M.* blast pipe, but owing to lack of space, transversely.

The *Est Rys.* have obtained similar results, but fit the moveable part with 6 wings.

3. Lemaitre blast pipe (fixed or variable).

The Lemaitre exhaust pipe used on certain engines of the *Belgian Nat. Rys. Co.*, the *Nord-Belge Lines*, the *French Nord* and *French State Rys.*, two particular features of which are shown in figures 23 and 24, is designed with multiple nozzles, generally arranged in a circle round a central blast pipe. This latter can be fitted with a moveable part so as to give a certain amount of variability to the blast (*French Nord* arrangement).

Figure 23 shows the application of the Lemaitre blast pipe, with 8 nozzles round a central oblong nozzle, to the *Belgian Rys. locomotives* of class 1 (1).

Figure 25. gives particulars of the Lemaitre blast pipe fitted to a *Pacific* locomotive of the *French State Rys.* and figure 26, particulars of it as applied to the 3.1200 locomotives of the *French Nord Ry.*

4. Duchatel fixed blast pipe.

In 1936, the *Est Rys.* have equipped one 4-6-0 locomotive with the Duchâtel blast pipe which has two laminiform nozzles parallel to the longitudinal centre line of the boiler, which discharge into two chimneys of rectangular section placed side by side.

5. P. L. M. clover-leaf variable blast pipe.

The *Alsace-Lorraine Rys.* have improved the clover-leaf blast pipes on 20 of their S.14 locomotives by increasing the section of the nozzle by 15 %, by

(1) Cf. *Bulletin of the Railway Congress*. May 1936, page 465. article by Mr. NOTESSE.

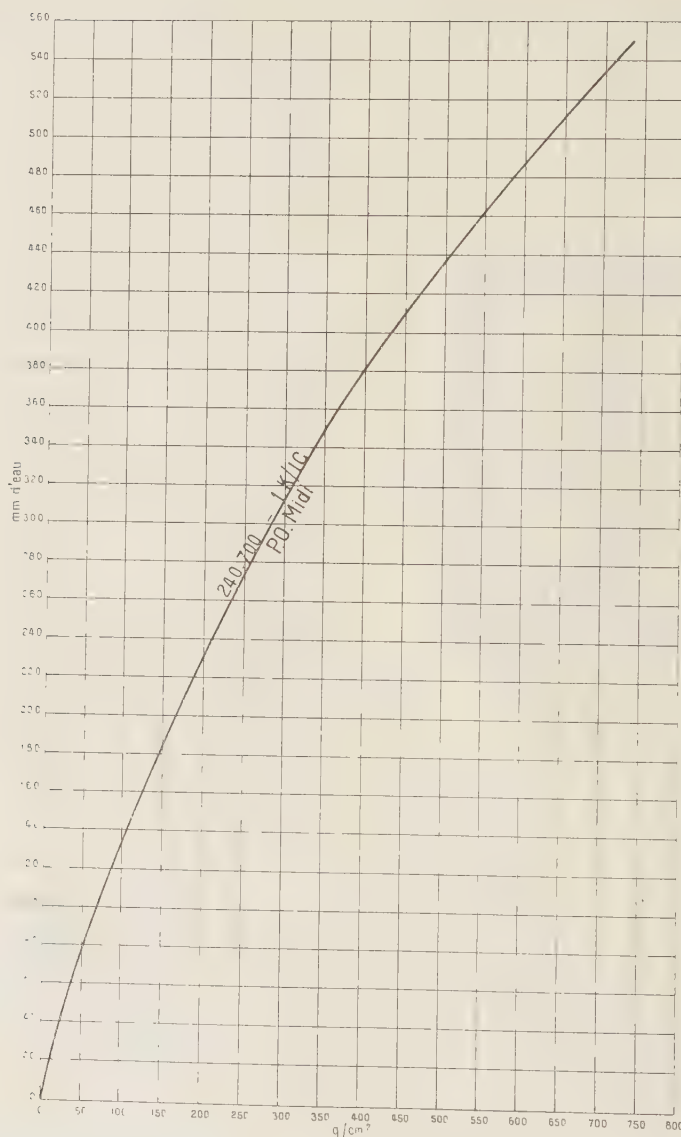


Fig. 20. — Characteristic curve of the IK/IC *Kylchap* double blast pipe.

modifying the design of the exhaust pipe, lowering the height of the blast pipe top, and by increasing the sectional area of the chimney from 830 to 2040 cm² (128 to 316 sq. in.).

III. — Comparison between fixed and variable blast pipes.

The opinion of the railways is divided as regards using a fixed or variable blast

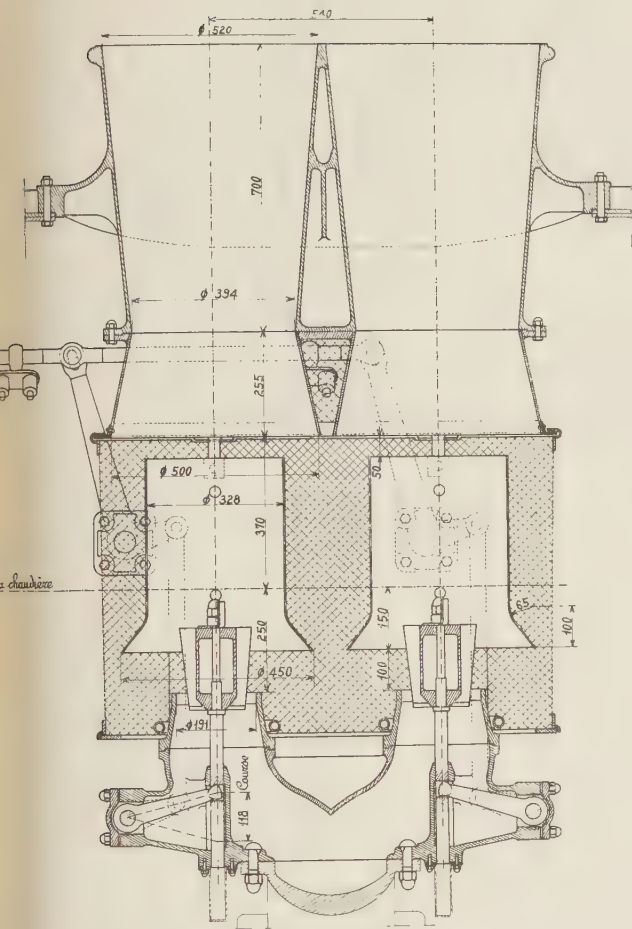


Fig. 21. — P.L.M. double blast pipe with cross bars fitted to the 151.A (2-10-2) locomotives of the P.L.M. Rys.

Note: Axe de la chaudière = centre line of boiler.
Course = stroke.

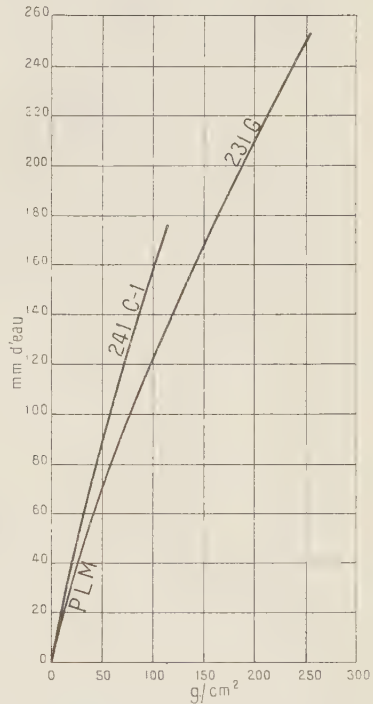


Fig. 22. — Characteristic curves of the double blast pipe with cross bars fitted to two types of P.L.M. locomotives.

Note: mm. d'eau = millim. of water. — g./cm² = grammes per square centimetre.

pipe. The *Reichsbahn*, the *Austrian Federal Rys.*, the *Finnish State Rys.*, the *P.O.-Midi Rys.*, the *Damas-Hamah Ry.*, the *Hungarian State Rys.*, and the *Netherlands Rys.* are in favour of a blast pipe with a fixed top.

On the other hand the *Est Rys.*, the *P.L.M. Rys.* and the *Algerian Rys.* definitely favour the variable blast pipe.

Apart from these opinions, the value

of the variable blast pipe top is recognised by : — the *Belgian Rys.* to increase the blast on starting, the exhaust being fully open afterwards; — the *Alsace-Lorraine Rys.* on engines having to work at very variable loads (provided the staff are trained); — the *French State Rys.*, according to the work to be done and the fuel to be burnt; in addition, in the case of oil-fired engines,

without stored heat double the quantity of oil can be burnt with the variable blast pipe in certain cases.

Obviously it is difficult to conciliate these very different points of view without going into the service difficulties, the quality of the fuel to be burnt and the skill of the available driving and maintenance staff.

Summary.

1. The use of improved blast pipes increases appreciably the power and efficiency of the locomotives.

2. Opinions of the railways are still divided as to the value of variable blast pipes.

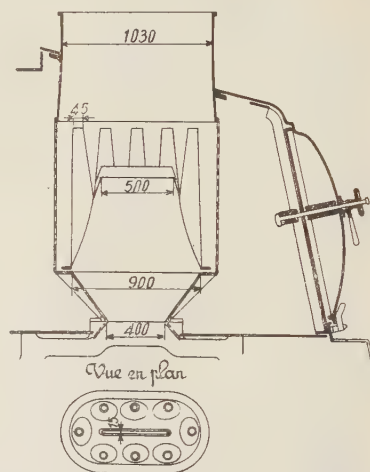


Fig 23. — *Lemaitre* blast pipe as fitted to the *Belgian National Railways Company's* type 1 locomotives.

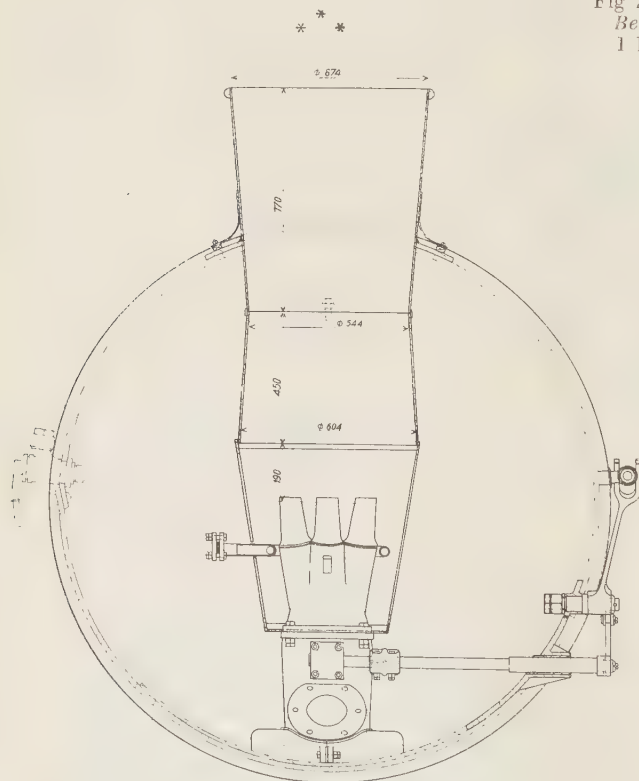
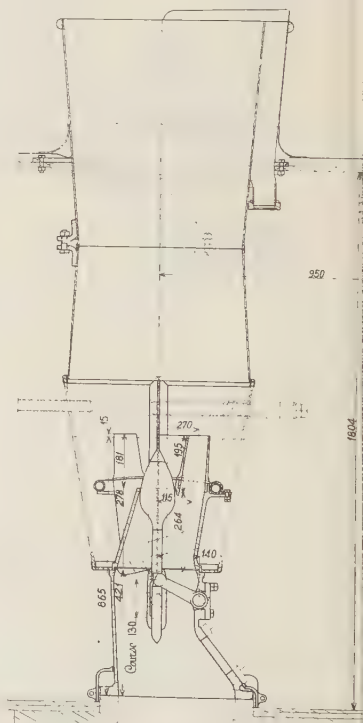


Fig. 24. — *Lemaitre* blast pipe as fitted to *French Nord* class 3.1200 locomotives.



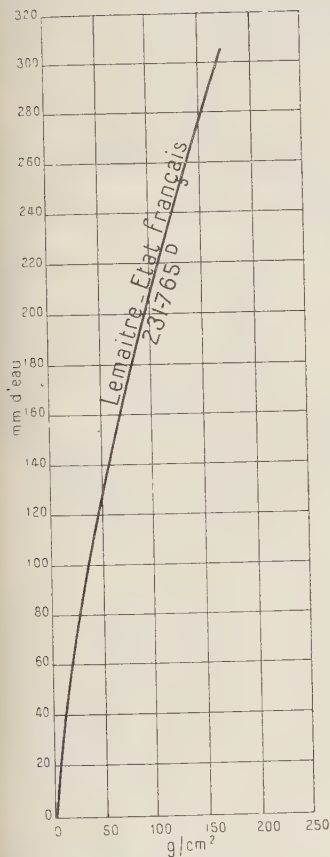


Fig. 25. — Characteristic curve of a *Lemaitre* blast pipe as fitted to a *French Nord* locomotive.

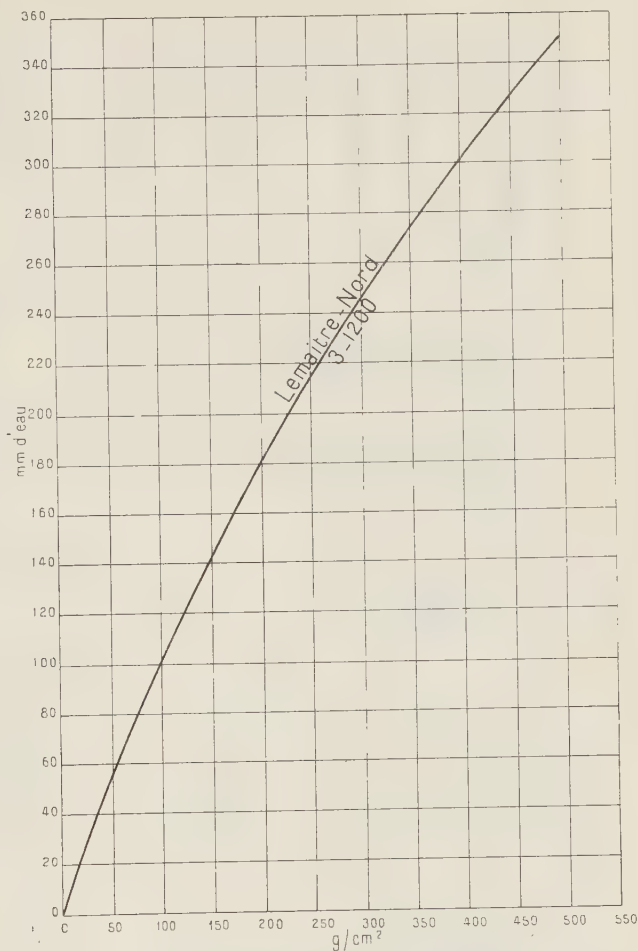


Fig. 26. — Characteristic curve of a *Lemaitre* blast pipe as fitted to a *French Nord* locomotive.

CHAPTER VIII.

Improvement of the valve gear.

I. — Improvements in the construction of pistons and valves.

Most of the Railways have endeavoured to reduce the weight of the reciprocating parts.

(a) *Pistons*. — The *Reichsbahn* on

its high-speed streamlined locomotives uses light pistons of pressed St.50 steel.

The *Est Rys.* are using at the present time, as a trial, a forged duralumin piston.

(b) *Piston valves*. — The piston valves have been lightened by improvements in design, i.e. reducing the thickness of the web, ribs and head, and by using hollow rods. The *Reichsbahn*, the *Belgian Nat.*

Rys. Co., the *Est* and *P.L.M. Rys.* have lightened the piston valves by these methods. The *Est Rys.* have been able to reduce the weight of their cast-steel high-pressure piston valves on their 4-8-2 locomotives, from 103.8 to 66.5 kgr. (229.8

to 146.6 lb.). The *P.L.M. Rys.*, following the design of the *Reichsbahn*, have reduced the weight of the high-pressure piston valves on their 4-6-2 locomotives from 68 to 38 kgr. (149.9 to 83.8 lb.) (fig. 27).

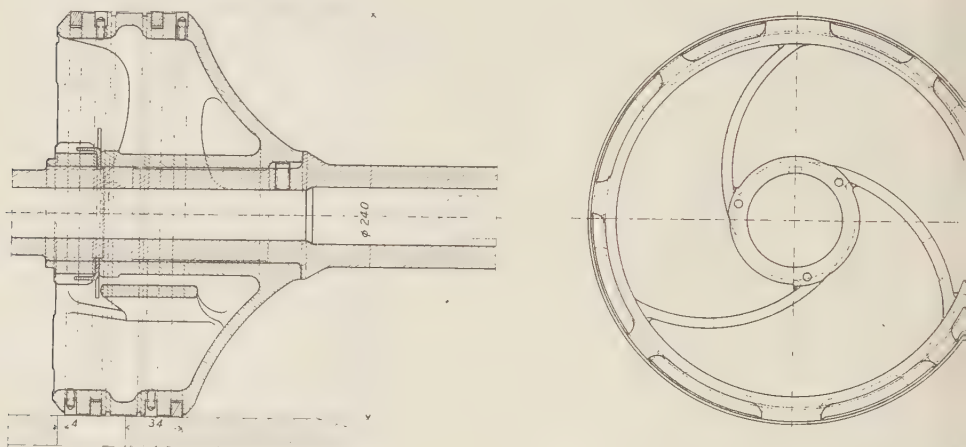


Fig. 27. — *P.L.M.* lightened piston valve.

The methods of construction of the piston valves have also been dealt with, welded plate having been used in place of cast iron or cast steel. The *Est Rys.*, with their « diabolo » type of piston valves (fig. 28), and the *P.L.M. Rys.* have

been able in this way to obtain very light piston valves. This type of valve appears, however, to be difficult to manufacture. The maximum possible lightness must be looked for especially when using double-ported valves, as these are more

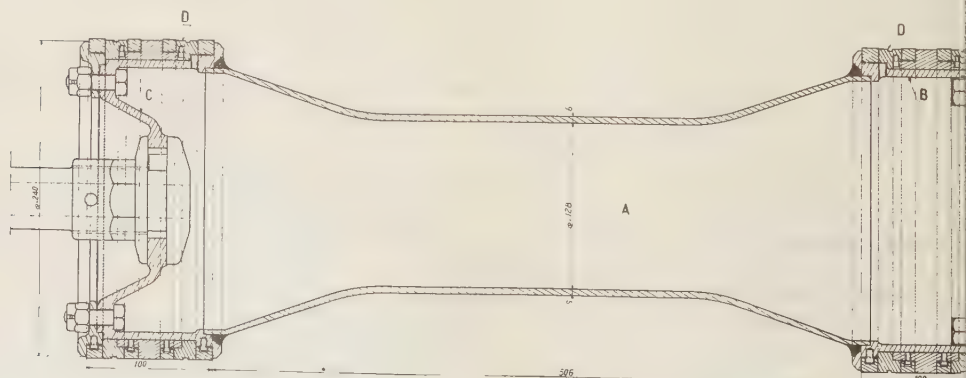


Fig. 28. — « Diabolo » type light piston valve of the *French Est Rys.*

A — valve body: weldless steel tube.
B — front head: open hearth A steel

C — back head: open hearth A steel.
D — spacer rings: F2 cast iron.

more voluminous than the ordinary piston valves. Here again the weight has been reduced, either by improvements in design, in the case of those used on the *Est Rys.*, or by welded construction, in the case of the double-ported valves of the *French State Rys.* and the Willoteaux valves on the *P.O.-Midi Rys.* The weights obtained are given below :

Railway.	Type of locomotives.	Low-pressure double-ported piston valves.			
		Material.	Diameter.	Weight.	Remarks.
Est	4-8-2	Malleable cast iron.	300 mm. (11 13/16")	93 kgr. (205 lb.)	...
		Cast steel.	300 mm. (11 13/16")	105 kgr. (231.5 lb.)	
P.O.-Midi	4-6-2	Welded plate.	350 mm. (13 3/4")	90 kgr. (198.4 lb.)	Willoteaux valves.

II. — Types of valve gear.

The classic *Walschaerts* valve gear with piston valves is still the most widely used on locomotives now in service. There has, however, been a considerable increase since 1930 in the number of special valve gears (long-stroke *Walschaerts* gear, double-ported piston valves, and poppet valves). Most of these valve gears can consequently be considered as having got beyond the experimental stage. The following table gives particulars of the number of such gears fitted or being fitted.

1. Long-stroke gears.

Report No. 1 on Question IV of the Madrid Congress gave particulars of the long-stroke valve gear used by the *Est Rys.* on their 2-6-2 suburban tank engines, in which the maximum stroke of the valves was increased from 135 to 273 mm.) 5 5/16" to 10 3/4"). This Administration has applied these valves to new 2-8-2 suburban locomotives with three simple-expansion cylinders and to the 4-8-2 compound locomotives (high-pressure motion), as well as to its older classes of locomotives, 4-6-0, Nos. 230.103 to 280, and 4-6-2, Nos. 231.001 to 040.

The French State Rys. have recently built 4-8-2 compound locomotives and 2-8-2 three-cylinder simple-expansion suburban locomotives of the same type as the corresponding series on the *Est*, with the same long-stroke valve gear. The *Nord* and *P.O.-Midi Rys.* have also used long-stroke valve gears. The *Est* prefers the long-stroke valve gear to any other, when it is a question of modifying a locomotive economically. When applied to a compound locomotive with a double-ported low-pressure piston valve, this arrangement gives results comparable with those obtained with oscillating cam valves. The *Nord* and *Alsace-Lorraine Rys.* agree with this point of view as regards compound locomotives, with which the cut-off is rarely below 20 to 30 %.

2. Double-ported slide valves.

The *P.O.-Midi Rys.*, on their 4-6-2 class 231-800 locomotives, are replacing the low-pressure slide valves by double-ported piston valves on the *Willoteaux* ⁽¹⁾ system. The *Willoteaux* piston valve consists of two identical piston valve bodies

(1) Cf. *Revue Générale des Chemins de fer*, September 1932, page 273.

STATISTICS OF SPECIAL VALVE GEARS.

	Deutsche Reichsbahn.	Austrian Federal-Rys.	Belgian Nat. Rys. (%)	Alsace-Lorraine.	Est.	State.	Novd.	P.L.M.	P.O.-Midi	Algerian Rys.
Number of locomotives in stock	22 500	1 900	3 037	1 095	2 200	2 947	2 146	4 800	2 648	714
Poppet valve gears	?	300	...	...	23	31	20	82	43	...
{ oscillating cams	...	...	...	1	2	60	...	...	...	...
{ low pressure only	...	...	...	6	27	99	94	92	...	...
{ rotary cams	?	...	...	5	2	8	74	40	...	13
Long-stroke piston valve gears.	..	...	...	...	349	89	...	...	3	...
Double-ported piston valve gears	2	...	15	...	259	48	...	...	17	1

placed end to end. Each consists of two cylindrical casings between which is an annular space reaching to the periphery of the valve which acts alternatively as an additional passage either for the exhaust or the admission (fig. 29).

The *French State Rys.* have applied Willoteaux piston valves to the low-pressure cylinders of eighteen 4-6-2 locomotives, and the Algerian Rys. have fitted one of their 4-8-2—2-8-4 articulated *Garratt* locomotives as a trial.

In the double-ported low-pressure piston valves fitted by the *Est Rys.* to their 4-6-0, 4-6-2 and 4-8-2 locomotives and the high-pressure piston valves designed for a 4-6-2 locomotive of the *French State Rys.*, the annular space mentioned above is divided by helicoidal partitions, into two passages, one of which is used for admission, and the other for exhaust (fig. 30).

On its new 25-kgr./cm.² (356 lb. per sq. in.) *Pacific* locomotive, the *Reichsbahn* has applied double-ported piston valves to the low-pressure pistons, and on their new type 1, 4-cylinder simple-expansion locomotives, the *Belgian Rys.* have used double admission slide valves.

The increase in the sections of the steam passages resulting from this arrangement has given excellent results on the railways which have used it. The *P.O.-Midi Rys.* have found important reductions in pressure loss between the intermediate receiver and the low-pressure cylinders, and in the back pressure at the exhaust, and an increase in the maximum available horse-power. The only disadvantage of this type of valve is its greater weight (see Chapter VIII-I).

3. Valve gears with limited cut-off.

Only one railway, the *Est*, has tested this type of valve gear on a 2-8-2 two-cylinder simple-expansion tank engine fitted with a long-stroke valve gear with the admission cut off at 50 %. The valve gear also had an auxiliary valve in addi-

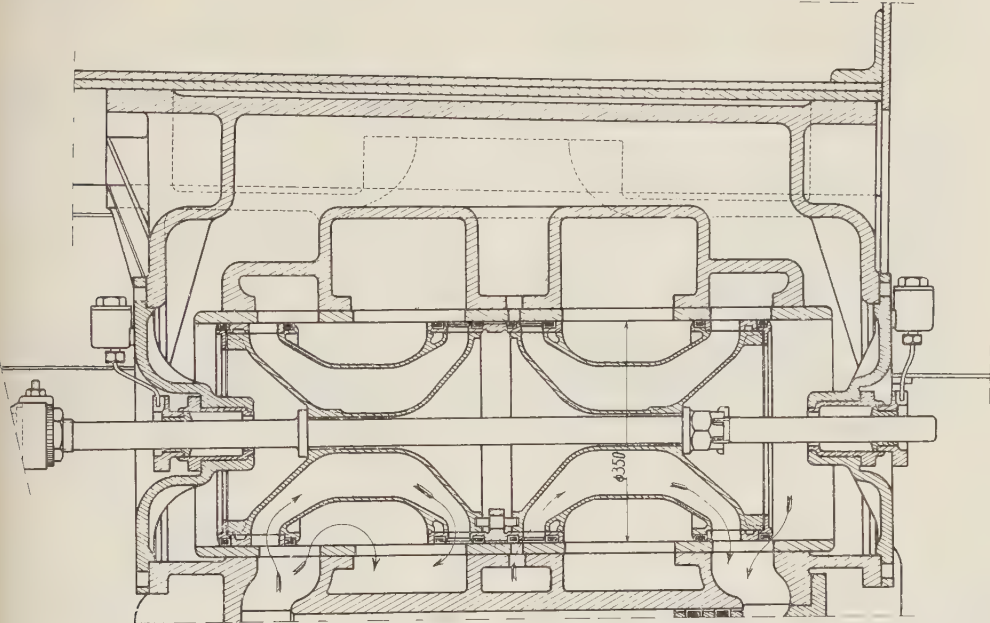


Fig. 29. — Willoteaux double-ported valve used on the P.O.-Midi Rys.

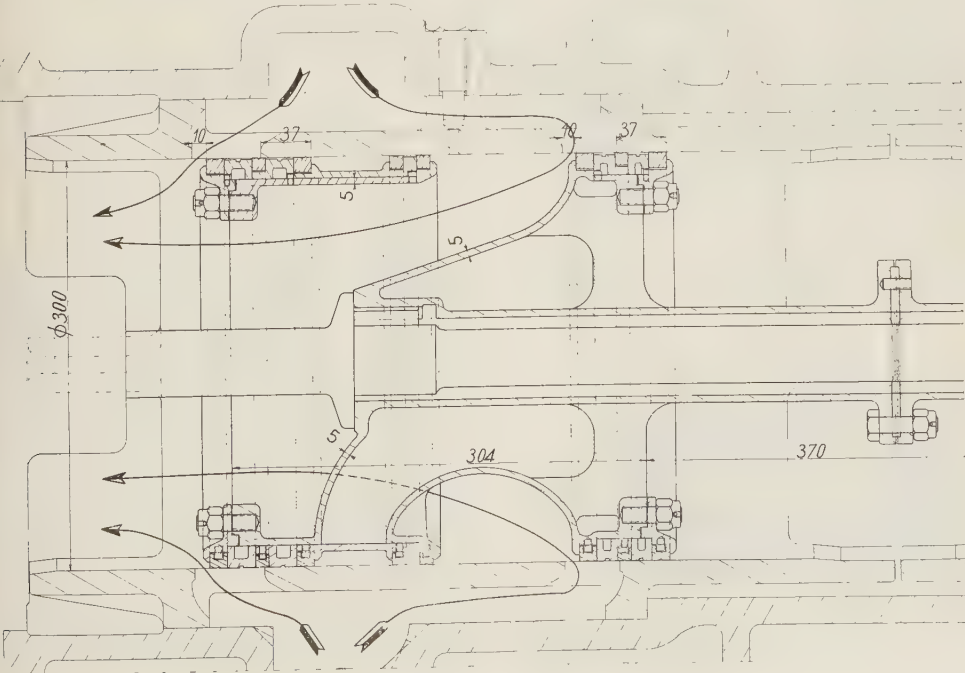


Fig. 30. — Double-ported valve used on the French Est Rys.

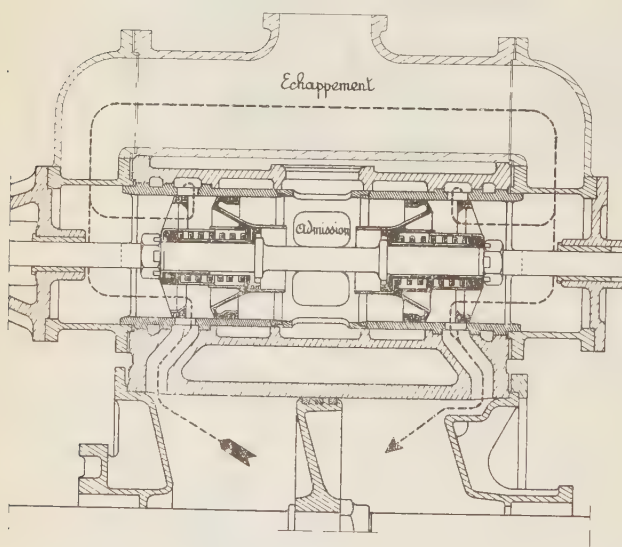
tion to the main valve, to facilitate starting.

The whole arrangement, therefore is an adaptation to a two-cylinder simple-expansion locomotive of the American 3-30 (1) valve gear provided for a 3-cylinder locomotive with cut-off limited to 30 %.

The test was satisfactory, but no appreciable increase in the motion efficiency was recorded.

The *State Rys.* have not applied this valve gear on any other locomotives.

Regulator shut.



Regulator open.

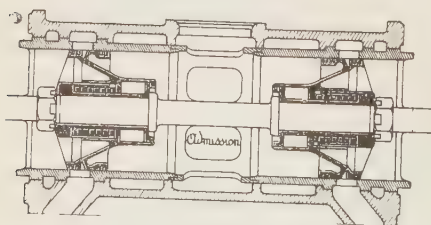


Fig. 31. — Nicolai piston valve, Deutsche Reichsbahn.

4. Nicolai piston valves.

The *Reichsbahn* has put into service on a certain number of locomotive piston valves of the Nicolai type, giving an automatic by-pass.

This piston valve in its design resembles the *Trofimoff* valves described in Report No. 1, Question VI, of the Madrid Congress.

As figure 31 shows, each piston valve consists of two rings, one of which on the inside is moveable and carries the piston body and is forced against the other by the steam pressure. When the regulator is shut the springs separate the two interior rings, and so put the two ends of the cylinder into communication with one another.

It should be noted that when running with the regulator shut, the Nicolai slide valve does not fully uncover the ports (the degree of opening being a function of the stroke of the valve) whereas in the *Trofimoff* valves the ports were fully uncovered.

5. Poppet valve gears.

a) *Oscillating cam poppet valve gear* of the *Lentz*, *Dabeg* and *Esslingen* systems.

(α) *Lentz and Dabeg valve gears.*

The reports to the Madrid Congress gave the principles of these valve gears which have moreover been described in many technical papers.

Since 1930, the *Dabeg* oscillating cam poppet valve gear has been improved in several ways.

The experiments were directed towards increasing the diameter of the poppet valves and their lift, at the same time as improving the section and seats of the valves. In 1930, the diameter of the poppet valves did not exceed 200 mm.

(1) Cf. *Bulletin of the International Railway Congress Association*, August 1931, page 720.

(7 7/8"). It is now 275 mm. (10 53/64") on the low-pressure exhaust valves of the 4-8-0, class 240.700 locomotives of the

P.O.-Midi Rys. Figure 32 shows the profile adopted for these valves and their seats.

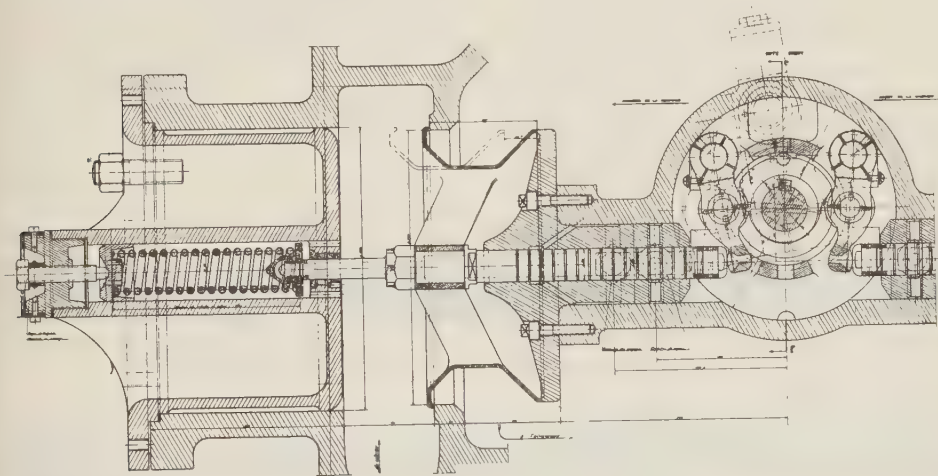


Fig. 32. — Low-pressure exhaust valve of the *Dabeg OC*, oscillating cam gear fitted to the *P.O.-Midi* 240.700 (4-8-0) locomotives.

Moreover, thanks to the profile of the cams it has been possible to increase the speed and height of lift, which latter can be as much as 32 mm. (1 17/64").

Poppet valve gears make it very easy to arrange a by-pass by lifting two opposite valves at the same time.

On the latest *Dabeg* valve gears, the by-pass is controlled by a compressed air servo-motor (fig. 33). The intermediate levers are mounted freely on 2 splined shafts, running in opposite directions, and driven by the servo-motor. Two fingers are engaged in the splines and can lift the intermediate levers and consequently the admission valves.

The *Dabeg* and *Lentz* oscillating cam valve gears are much the most widely used poppet valve gears on the Railways consulted.

The *Reichsbahn* is testing *Lentz* poppet valve gears.

The *Austrian Rys.* have used the *Lentz* valve gear on many occasions, and in

particular on all the 214 class recent locomotives of the 2-8-4 type.

The *P.L.M. Rys.* have built two classes of compound suburban engines of the 4-8-4 type, 81 altogether, all equipped with *Dabeg* valve gear. They are also as an experiment fitting one 4-6-2 locomotive.

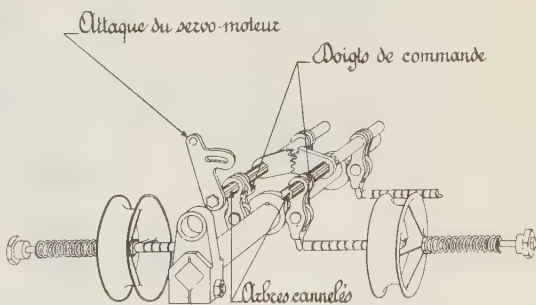


Fig. 33. — Operation of by-pass on *Dabeg O.C.* oscillating cam gear.

Note: *Attaque du servo-moteur* = drive from servo-motor. — *Doigts de commande* = driving fingers. — *Arbres cannelés* = splined shafts.

The *P.O.-Midi* Rys. have equipped forty-three 4-6-2 and 4-8-0 compound locomotives with *Dabeg* valve gear to both high-pressure and low-pressure cylinders. The *Est* has twenty-three 4-6-2 locomotives of the same type, and the *Nord* 20.

The *French State* Rys. have altered sixty 4-6-2 locomotives by fitting the *Dabeg* valve gear to the low-pressure cylinders only. They have in addition fitted one 4-6-2 locomotive as a trial with the *Dabeg* valve gear on the high-pressure and low-pressure cylinders, and at the present time are altering in this way thirty 4-6-2 locomotives.

The *Est* and *Alsace-Lorraine* have also applied the *Dabeg* valve-gear on the low-pressure cylinders of some of their 4-6-2 locomotives.

(β) *Maschinenfabrik Esslingen* valve gear.

The *Reichsbahn* is making tests with a valve gear designed by the *Esslingen* Works. This is a valve gear with oscil-

lating cams, the admission and exhaust cams being operated independently.

Separate steam passages are provided for the valves which reduces the dead space and avoids all contact between the live steam and exhaust steam.

Figure 34 shows the arrangement.

b) *Rotary poppet valves, Caprotti, Dabeg and Renaud* design.

These valve gears were described in the reports to the 1930 Congress. Although less widely used than the oscillating cam gears, they have nonetheless given valuable results. They appear to be particularly suitable for extra-high-speed locomotives, owing to the small inertia of the moving parts.

(α) *Caprotti* valve gear.

The *Reichsbahn* has made a number of tests of the *Caprotti* valve gear.

The *Alsace-Lorraine* Rys., as a result of satisfactory tests on a P.8 (4-6-0) locomotive, have built two *Pacific* S.16

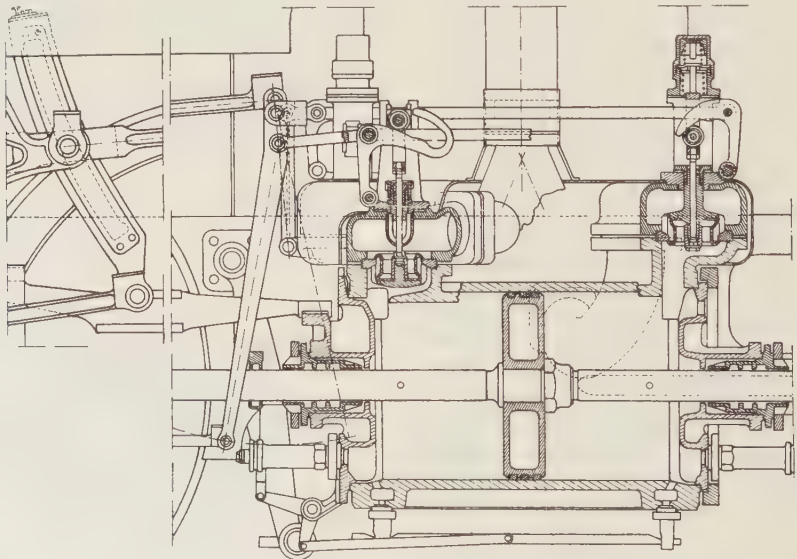


Fig. 34. — *Esslingen Maschinenfabrik* valve gear.

type two-cylinder simple-expansion locomotives ⁽¹⁾ and have ordered two G.16 Santa Fe type three-cylinder simple-expansion locomotives with this gear. The G.16 locomotives will have the valve gear operated by two cam boxes only; each of these cam boxes will operate the valves of one outside cylinder and two of the valves of the inside cylinder.

(β) *Dabeg valve gear.*

The *P.L.M. Rys.* built in 1931 ten 2-10-2 locomotives fitted with *Dabeg R.C.* valve gear, which have behaved very well in service.

The tests with continuous cams (fig. 35), which have given good results so far in place of the stepped cams originally fitted (fig. 36), should be noted.

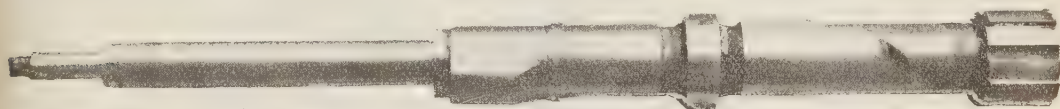


Fig. 35. - *Dabeg R.C.* rotary cam shaft with continuous cams.



Fig. 36. — *Dabeg R.C.* rotary cam shaft with stepped cams.

(γ) *Renaud valve gear.*

The *Renaud* valve gear has been fitted by the *French State Rys.* to a 3-cylinder simple-expansion 4-8-2 locomotive, to a 3-cylinder simple-expansion 4-6-2 locomotive, and to six 4-6-2 compound locomotives (low-pressure cylinders only).

c) *Cossart valve gear* ⁽²⁾ with piston valves.

The *Cossart* valve gear has rotary cams with independent valve events.

The cams drive piston valves through rollers (fig. 37). These piston valves, which the *Nord Ry.* prefers, after tests, to poppet valves, have the advantage of reducing wire-drawing as they are moving at speed when the ports are uncovered. In addition the use of piston

rings makes it easy to keep the valves tight in service, and the form of the piston valves is such that they can be balanced perfectly.

The cams are three in number. One exhaust cam opens and closes the corresponding piston valve. This cam is fixed and gives constant compression. The admission piston valve is operated by a set of two rollers running on two cams, one of which, the admission cam, is fixed, and gives a fixed linear advance, and the other, known as the release cam, forms a variable angle with the first, which makes it possible to alter the release.

All these cams are symmetrical in profile, and the reversing is obtained by rotating them simultaneously the correct amount on the shaft driving them.

The *Nord Ry.* has fitted the *Cossart* valve gear to seventy-two 2-8-2 suburban tank engines and 2 *Pacific* locomotives.

Consequent upon the satisfactory results obtained with this gear on the

(1) Cf. *Revue Générale des Chemins de fer*, May 1935, p. 481, article by M. REGNAULD.

(2) Cf. *Revue Générale des Chemins de fer*, February 1933, page 148, article by M. COSSART.

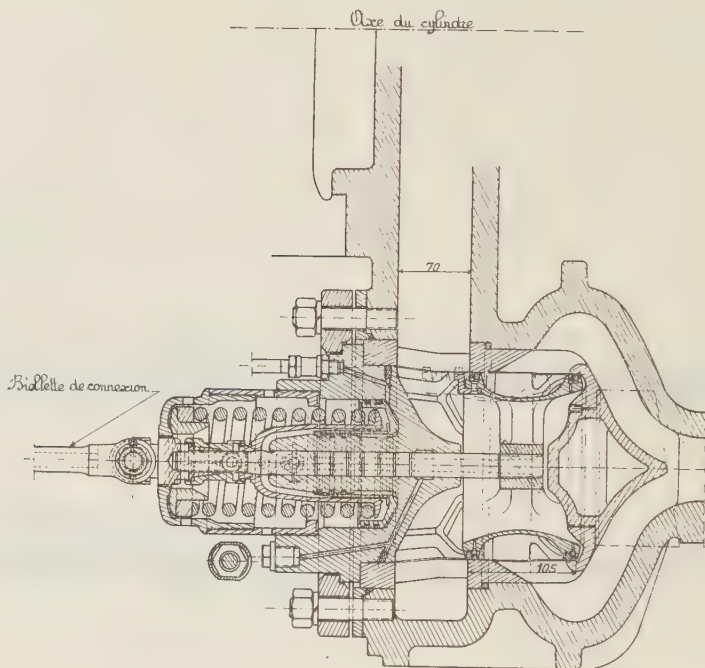


Fig. 37. — Piston valve of *Cossart* valve gear.

Note: Axe du cylindre = centre line of cylinder. — Bielle de connexion = link.

Beyer-Garratt 4-6-2—2-6-4 AT-1 locomotive the *Algerian Rys.* have ordered twelve 4-6-2—2-6-4 BT locomotives with this valve gear.

III. — Conjugated and non-conjugated (independent) valve gears.

The opinions of the railways have not changed since the Madrid Congress.

The *Reichsbahn*, *Belgian Rys.*, *Est* and *P.O.-Midi Rys.* favour independent valve gears in the case of compound locomotives. The *P.L.M.* on the other hand has only conjugated valve gears on its modern locomotives, and is quite satisfied with them.

IV. — Summary.

1. The use of double-ported piston valves is apt to improve the distribution of steam to the cylinders.

2. Poppet valve gears are beyond the experimental stage and can be fitted as standard practice to locomotives.

3. Poppet valves or piston valves operated by oscillating or rotary cams have given very good results under test. It is not possible, however, to separate the part due to the valves themselves from that due to other improvements in the locomotives.

4. Poppet valves or piston valves operated by rotary cams, owing to the small inertia of their moving parts, appear to be specially suitable for extra-high speed locomotives.

* * *

CHAPTER IX.

Improvements in the steam circuits

Following the particularly favourable results obtained on certain Railways,

most Administrations have investigated and improved in a large measure the steam passages. Naturally the extent of the alterations has varied, as in most cases the Railways were not dealing with new engines but with locomotives which they wished to improve without making too costly alterations.

The principles on which these investigations were based are not new, but had been more or less lost to view. They were taken up again by the *P.O.-Midi Rys.* when rebuilding their *Pacific* engines some as 4-6-2 (231.700) and others as 4-8-0 (240.700) :

Mr. Barbier in his paper published in the March, June and July 1898 numbers of the *Revue Générale des Chemins de fer*, showed that to obtain the maximum efficiency of compound locomotives the following conditions must be respected :

1. The steam circuits must be such that the loss of pressure between the boiler and the high-pressure cylinders, between the high-pressure cylinders and the low-pressure cylinders, and between the low-pressure cylinders and the atmosphere, shall be the minimum;

2. Large admission ports and sufficient clearance spaces must be provided to prevent wire-drawing and excessive compression in the cylinders;

3. The receiver capacity must be large to avoid marked variations in pressure, which occur when this volume is inadequate;

4. The high-pressure and low-pressure valve gears must be independent, so that under all running conditions the best combination of high-pressure and low-pressure cut-offs can be used.

The dimensions adopted when rebuilding the *P.O.-Midi Pacifics* and the results obtained were described in the July 1931 and March 1932 numbers of the *Revue Générale des Chemins de fer*.

These principles which cover the whole of the steam circuit, from the boiler to the exhaust, are so general in cha-

racter that all the Railways, in endeavouring to improve existing stock or in getting out new designs, have taken them into account. Some reserve is made, however, as regards the independance of high-pressure and low-pressure valve gears ; there is no reason why once the best combination has been found by trials on a locomotive, conjugated valve gears should not be fitted on the other locomotives of the same series (see chapter VIII).

The *Belgian National Rys. Co.* has endeavoured to make the steam circuits as direct and as large and uniform in section as possible ; the superheater is provided with sufficient elements to keep down the steam speed, whilst obtaining a satisfactory superheat temperature. The ports have been so arranged and dimensioned that at the highest speed and maximum rate of evaporation, the most favourable steam speed is obtained. This condition led to the use of double-admission valves. Finally the back pressure at exhaust has been reduced by selecting a blast pipe of adequate capacity.

In the case of recent superheated locomotives, the speed of the saturated steam through recent designs of superheater has been reduced from 35 to 18 m. (125 to 59 ft.) per second ; that of the superheated steam, which is 23 m. (75.4 ft.) per sec. on leaving the superheaters, has been reduced to 17 m. (55.7 ft.) per sec. instead of 35 m. (82 ft.) per sec. on leaving the headers. The speed of the exhaust steam is 30 m. (98.4 ft.) per sec. from the high-pressure and 75 to 80 m. (246 to 262.5 ft.) per sec. from the low-pressure cylinders ⁽¹⁾.

By following these guiding principles when altering the 4-6-0 locomotives, the maximum pressure loss between the boiler and receiver was reduced to 0.75 kgr./cm² (10.7 lb. per sq. in.) ; the pres-

(1) This speed is also admitted on simple-expansion locomotives.

sure at the low-pressure cylinder has reached 4 kgr./cm² (56.8 lb. per sq. in.) and the back pressure at exhaust 0.4 kgr./cm² (5.68 lb. per sq. in.) at maximum power.

The *Alsace-Lorraine Rys.* have increased the steam passages in the steam pipes and in the superheaters. Thus, on their S.14 locomotives, the section of the steam pipes has been increased to 254.5 cm² (39.8 sq. in.), the same section being adopted for the Crampton steam pipes on the S.16 and G.16 locomotives, and for the main steam pipes on the

latter. On the S.16 locomotive the section of the main steam pipes has been made 320.5 cm² (49.7 sq. in.).

The *Est Rys.* have reduced the pressure drop by a very careful study of the shape and section of the steam passages, in the cylinders and of the pipes. They have endeavoured in particular to avoid any sharp changes in section by making the variations gradual, and always in the same direction as the flow of steam.

As an example the sections adopted when altering the 4-6-2 (231,000) locomotives were as follows :

Passages.		High pressure.	Low pressure.
Main steam pipes		153.8 cm ²	254.5 cm ²
Exhaust pipes (minimum section)		254 cm ²	568 cm ²
Admission ports		311 cm ²	848 cm ²
Blast pipe top		234 cm ² (exhaust released)	
		145 cm ² (exhaust throttled)	
Chimney }	at the choke (diameter)	500 mm.	
	at the top (diameter)	620 mm.	

The pressure drop at the maximum power between boiler and receiver has been reduced to 0.5 kgr./cm² (7.1 lb. per sq. in.).

The *French State Rys.* have endeavoured to limit the steam speed to 50 m. (164 ft.) per sec. under maximum boiler output, as well as to eliminate sharp bends and projections in the steam circuits.

The result has been to increase the steam passages to the regulator and the dimensions of the superheater elements.

The *Nord Ry.* has increased the section of the main steam pipes either by increasing their diameter (on the 3.1200 locomotives) or by adopting double main steam pipes (on the 4.1200 locomotives).

In addition, they have reduced the

pressure drop at admission and exhaust either by substituting very large-diameter and long-stroke piston valves for the slide valves on engines still so equipped, or by increasing the diameter of the piston valves.

The 5 000 class engines have been given low-pressure cylinders 350 mm. (13 3/4") in diameter and the high-pressure piston valve diameter has been increased to 300 mm. (11 13/16").

The *P.L.M. Rys.*, have used different methods according to the type of engines modified.

The 4-6-2-G locomotives have been given new low-pressure cylinders with larger steam passages and a double *P.L.M.* exhaust giving an exhaust passage with the blast pipe fully open of 274 cm² (42.5 sq. in.) and of 181 cm² (28.1 sq. in.) when throttled. In addition the

piston valve bodies have been so designed as to offer a progressively increasing section so that all the ports can receive and discharge the steam.

Summary.

The Railways all agree in recognising the value of improving the steam passages of locomotives to the maximum possible extent.

* * *

CHAPTER X.

Compounding.

The opinions of the Railways are still very divided as regards compounding.

The *Reichsbahn* considers that compounding is of value only when the pressure exceeds 20 kgr./cm² (284 lb. per sq. in.).

The *Austrian, Netherlands, Hungarian and Finnish State Rys.* have no compounding locomotives and are not considering their use.

Simple expansion is preferred by the *Alsace-Lorraine Rys.*, and also on the *Nord* today, since the Cossart piston valve gear has been introduced.

The other *French Rys.* and the *Algerian Rys.* are in favour of compounding.

It must be admitted that as a result of the improvements made in locomotives in recent years, the reasons in favour of compounding have lost part of their value.

The results obtained by the *Alsace-Lorraine* and the *Nord Rys.* when using poppet valves with independent valve events, improved steam passages and high superheat, show that economical simple-expansion engines can be designed.

The damage to the frame, ascribed to hunting in the case of 2-cylinder simple simple expansion locomotives owing to their bad balancing, can be avoided, in the opinion of the *Alsace-Lorraine Rys.*, by using bar frames.

The *P.O.-Midi Rys.* point out that as perfect balancing as possible, involving a return to compounding, will be found necessary for very high speeds. This is not the opinion of the *Reichsbahn*; its streamlined locomotives which under test exceeded 200 km. (124 miles) an hour, are three-cylinder simple-expansion engines.

Summary.

The opinions of the railways are still divided as regards compounding.

* * *

CHAPTER XI.

Power and efficiency of modern locomotives.

The improvements described in the previous chapters have made it possible to increase the power and efficiency of the locomotives to an appreciable extent.

The following curves show the results obtained, usually during constant-speed tests, with the undermentioned locomotives.

(1) Six-coupled *Pacific* type locomotives:

- 03 of the *Reichsbahn*;
- 1 of the *Belgian Rys.* (1);
- S 16 of the *Alsace-Lorraine Rys.* (2);
- Original 231.644 DD of the *French State Rys.*;
- 231-G (3) and 231-H (4) of the *P.L.M.*;
- 231.722 to 731 of the *P. O.-Midi* (5).

(1) Cf. *Bulletin of the Railway Congress*, May 1936, p. 465, article by M. NOTESSE.

(2) Cf. *Revue Générale des Chemins de fer*, May 1935, p. 481, article by M. REGNAULD.

(3) Cf. *Les transports*, December 1934, p. 129.

(4) Cf. *Les Chemins de fer et les Tramways*, November 1933, p. 260, article by M. SPIESS, and *The Locomotive*, 15th May 1935.

(5) The 231. 722 to 731 *Pacific* locomotives are derived, with some improvements, from locomotive No. 3566 described in the *Revue Générale des Chemins de fer*, July 1931, page 18, article by M. CHAPELON.

(2) Eight-coupled locomotives.

— 214 ⁽⁶⁾ 2-8-4 type of the *Austrian Federal Rys.*;

— 241.000 of the *French Est*;

— 241 C of the *P.L.M.* ⁽⁷⁾;

— 240.700 ⁽⁸⁾ of the *P. O.-Midi*;

— Pt 31, 2-8-2 type, and Pu 29, 4-8-2 type of the *Polish State*;

— 424, 4-8-0 type of the *Hungarian State*;

— 6300, 4-8-4 type of the *Netherlands Railways*.

(3) Ten-coupled locomotives :

— 150.000 of the *Est Rys.*;

— 5.1200 ⁽⁹⁾, 2-10-0 type of the *Nord Ry.*;

— 151.A ⁽¹⁰⁾, of the *P.L.M. Rys.*;

— O.Kz 32, 2-10-2 type tank engine of the *Polish State*.

The characteristics of these various locomotives are given in Table I.

All these locomotives are superheated, and most of them had a feed water heater or exhaust steam injector.

I. — Boiler efficiency.

According to the railways the boiler efficiency is given relatively to the upper calorific value or the lower calorific value of the fuel. It would be desirable that all the figures were got out in the same way, to make it easier to compare them.

The efficiency of the boiler is about 0.7 for an hourly rate of combustion of 500 kgr./m² (102.5 lb. per sq. ft.). It falls to 0.5 when the rate of firing reaches 1 000 kgr./m² (205 lb. per sq. ft.) per hour (figs. 38 and 39.)

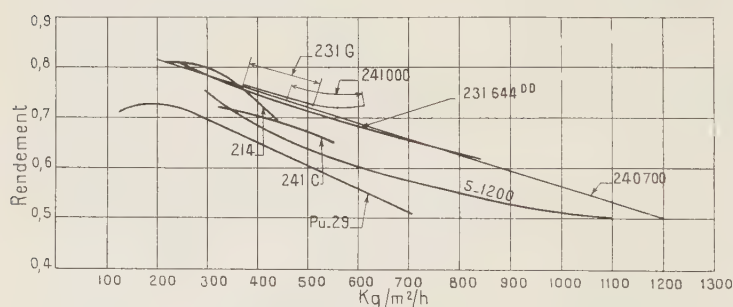


Fig. 38. — Boiler efficiency at different rates of combustion.

Note: The efficiency is in relation to:

— the higher calorific value of the fuel for the *French State, P. L. M. and Royal Hungarian State Rys.*

— the lower calorific value of the fuel for the *Reichsbahn, Austrian Federal, Alsace - Lorraine, French Est, Nord, P. O.-Midi, Netherlands and Polish State Rys.*

Rendement = efficiency.

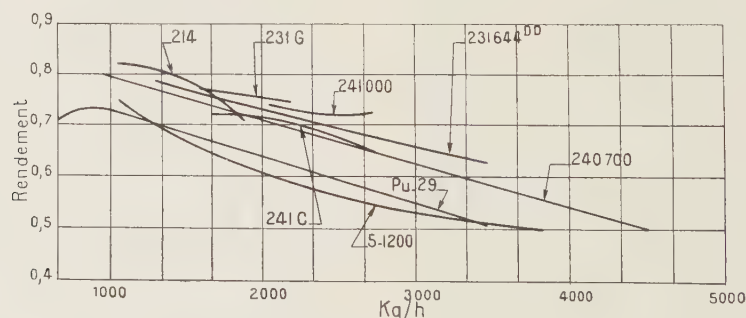


Fig. 39. — Boiler efficiency in terms of the total fuel consumption per hour.

⁽⁶⁾ Cf. *Bulletin of the Railway Congress*, January 1935, p. 68, article by Mr. NEBLINGER.

⁽⁷⁾ Cf. *Revue Générale des Chemins de fer*, September 1932, page 187, article by M. PARMANTIER.

⁽⁸⁾ Cf. *Revue Générale des Chemins de fer*,

February 1935, page 109, and March 1935, page 259, article by M. CHAPELON.

⁽⁹⁾ Cf. *Bulletin of the Railway Congress*, May 1934, page 492.

⁽¹⁰⁾ Cf. *Revue Générale des Chemins de fer*, January 1934, article by M. PARMANTIER.

II. — Evaporative power.

To compare accurately the evaporative power of different locomotives, the idea of the fictive evaporative power should be resorted to (*). Unfortunately only three Railways used this idea.

The hourly gross evaporative power reaches 80 to 90 kgr./m² (16.4 to 18.4 lb. per sq. ft.) of heating surface for rates of combustion of 500 to 600 kgr./m² (102.5 to 129 lb. per sq. ft.) of grate area per hour, and exceeds 110 kgr./m² (22.5 lb. per sq. ft.) for a rate of 1 200 kgr./m² (225 lb. per sq. ft.) per hour (figs. 40, 41 and 42.)

III. — Superheat temperature.

The temperature of the steam in the steam chests is some 380° to 390°C. (716 to 734°F.) for a gross evaporative power of some 80 kgr./m² (16.4 lb. per sq. ft.) per hour, and 370°C. (698°F.) for an evaporative power of some 60 kgr./m² (12.3 lb. per sq. ft.) per hour. (figs. 43, 44 and 45.)

IV. — Power of locomotives.

(a) *Effective and indicated horsepower.*

Figures 46 to 55 reproduce the curves

of the indicated (Pi) and effective (Pe) powers.

It would have been useful if, as requested, the various Railways had indicated how long the maximum powers could be sustained.

With the *Pacifics* indicated H.P. of 3 300, and effective H.P. of 2 500 can be sustained at 120 km. (75 miles an hour.)

With 8-coupled locomotives at 110 km. (68.3 miles per hour) 4 050 indicated H.P. and 4 050 effective H.P. can be sustained.

With 10-coupled locomotives 3 000 effective H.P. has been reached at 75 km. (46.6 miles) an hour.

(b) *Power at the tread of the driving wheels.*

During trials at the Vitry test plant, the powers given below, measured at the driving wheel tread, were maintained during two hours :

— 2 795 H.P. at 100 km. (62 miles) an hour by the *Est Ry. Mountain* locomotive.

— 3 032 H.P. at 100 km. (62 miles) an hour and 2 924 H.P. at 120 km. (75 miles) an hour by the *P.L.M. 231,H-141 Pacific*.

(*) The gross evaporative power of a boiler is by definition the weight of usable steam leaving the boiler in a given time, less the quantity of steam used to operate the pumps and injectors.

In the case of a boiler fed solely by an injector, the gross evaporative power is equal (ignoring any losses) to the quantity of water taken from the tender; in the case of a boiler fed with a closed type feed water-heater, the gross power is equal (always ignoring losses) to the quantity of water taken from the tender increased by the quantity of exhaust steam taken by the heater.

In a given boiler the gross power depends upon the temperature of the feed water; in the case of different boilers the gross power

depends in addition upon the boiler pressure and the superheat temperature. Therefore, in order to be able to make comparisons, the evaporative power must be calculated relatively to a fictive production of steam of a total known heat. The actual production should be converted to the equivalent production of saturated steam at 100° C. (232° F.) with a feed water temperature of 0° C., i.e. steam at 640 calories.

The fictive evaporative power of a boiler therefore can be defined as the quantity of steam at 640 calories which can be produced by the quantity of heat supplied to the boiler by the combustion of the fuel.

(Cf. *Revue Générale des Chemins de fer*, September 1932, page 198.)

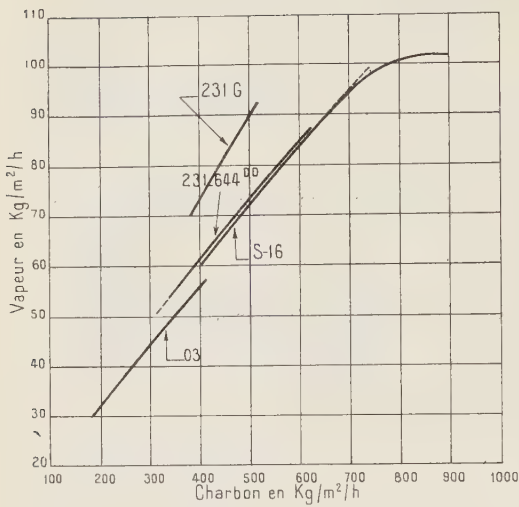


Fig. 40. — Gross evaporative capacity in terms of the rate of firing (*Pacific locomotives*).

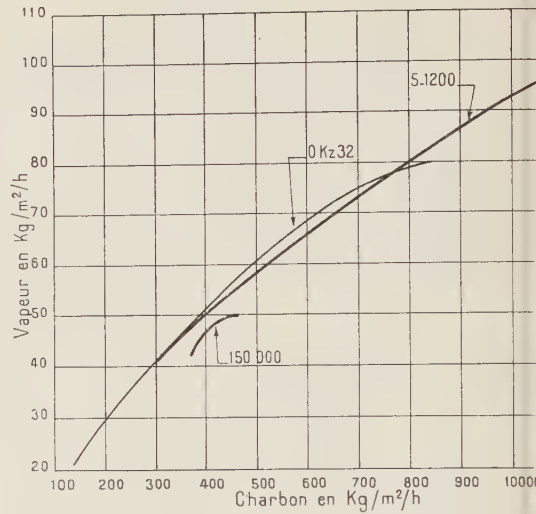


Fig. 42. — Gross evaporative capacity in terms of the rate of combustion (*10-coupled locomotives*).

Note: Vapeur = steam. — Charbon = coal.

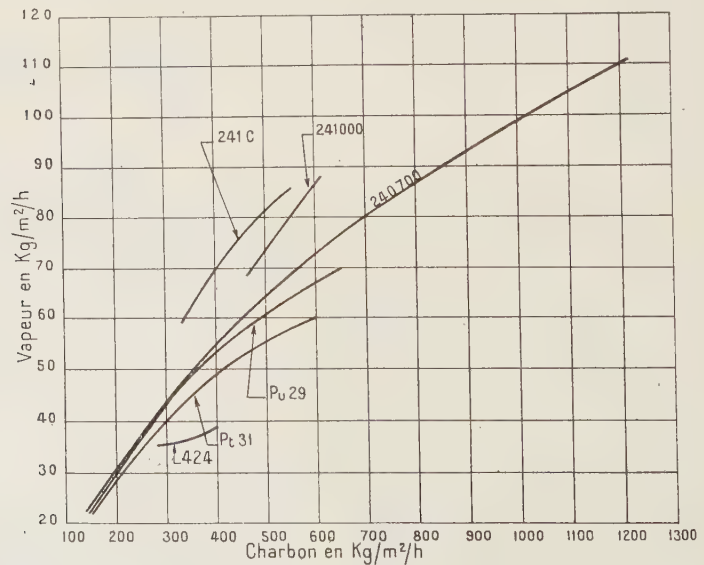


Fig. 41. — Gross evaporative capacity in terms of the rate of firing (*8-coupled locomotives*).

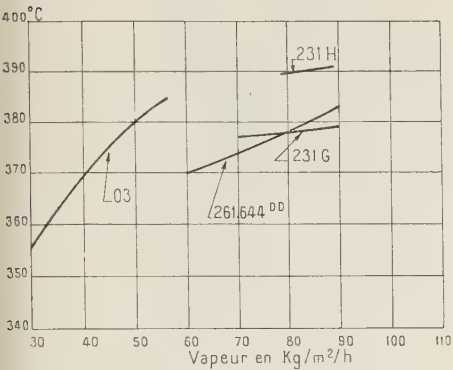


Fig. 43. — Superheat temperature in the steam chests in terms of the evaporative capacity (*Pacific locomotives*).

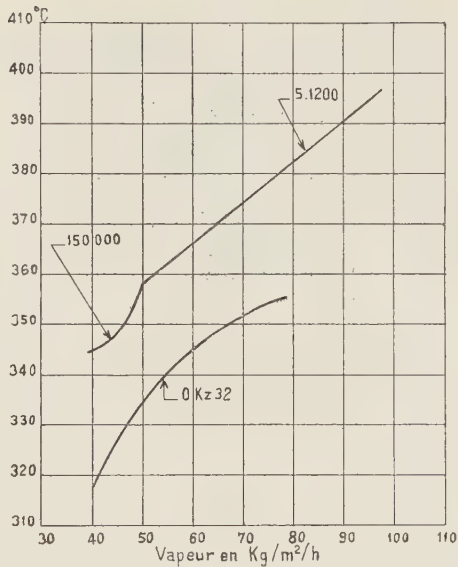


Fig. 45. — Superheat temperature in the steam chests in terms of the evaporative capacity (*10-coupled locomotives*).

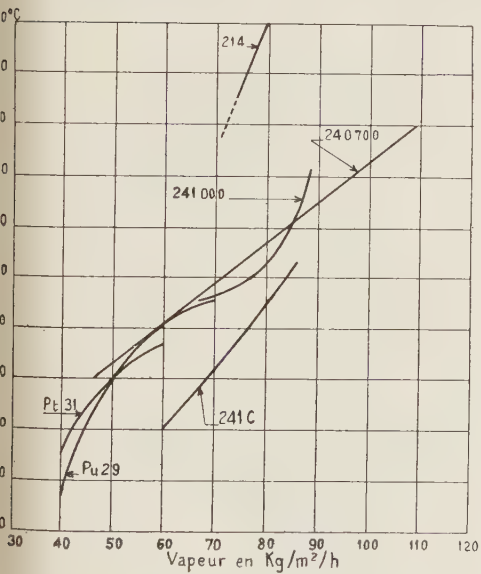


Fig. 44. — Superheat temperature in the steam chests in terms of the evaporative capacity (*8-coupled locomotives*).

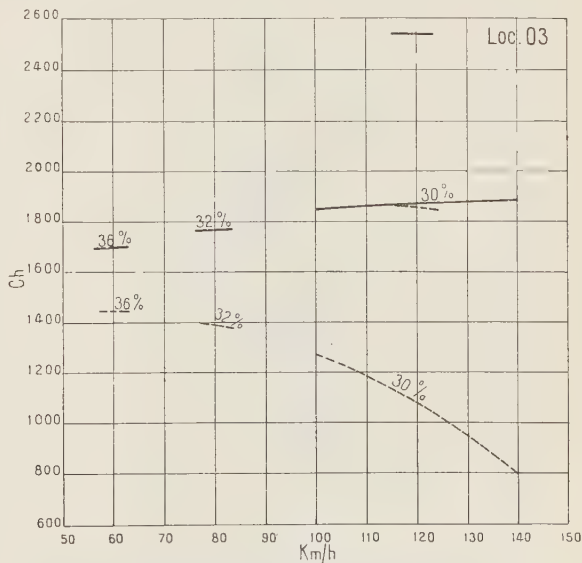


Fig. 46. — Indicated and drawbar horse-power, *Reichsbahn 03* type locomotives.

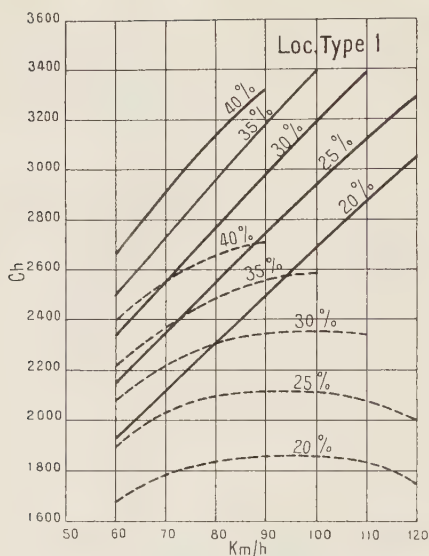


Fig. 47. — Indicated and drawbar horse-power, Belgian Nat. Rys. Co. type 1 locomotives.

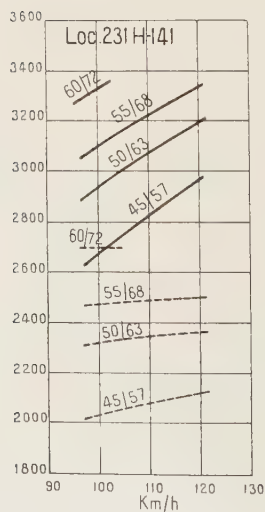


Fig. 49. — Indicated and drawbar horse-power, P.L.M. 231.H.141 locomotive.

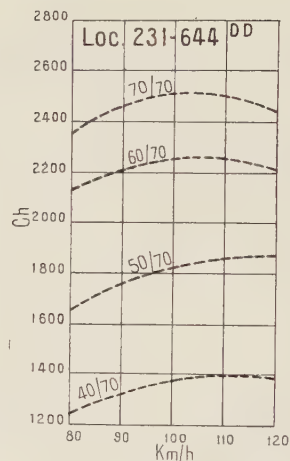


Fig. 48. — Drawbar horse-power, French State 231.644^{DD} (4-6-2) locomotive.

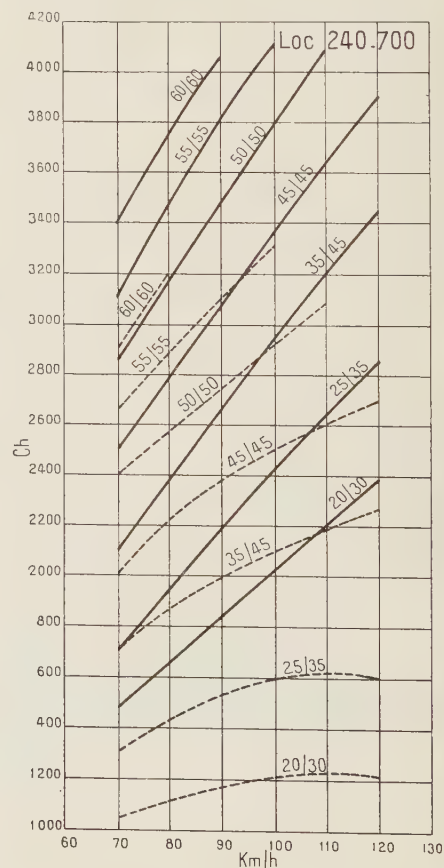


Fig. 50. — Indicated and drawbar horse-power, P.O.-Midi 240.700 locomotives.

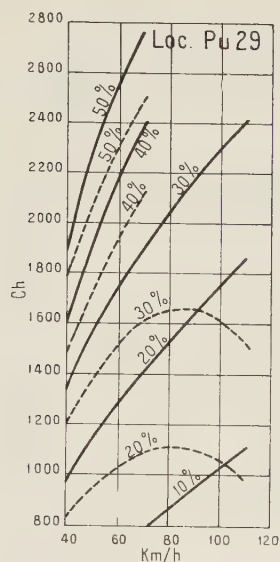


Fig. 51. — Indicated and drawbar horse-power, Polish State Rys. Pu 29 locomotive.

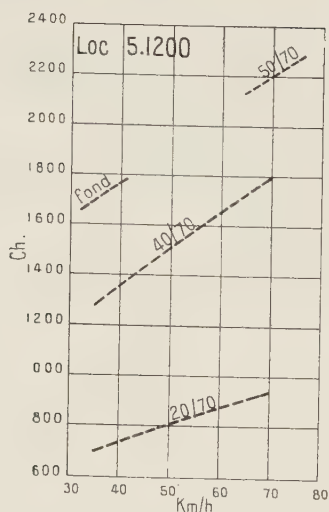


Fig. 53. — Drawbar horse-power, French Nord 5-1200 locomotives.

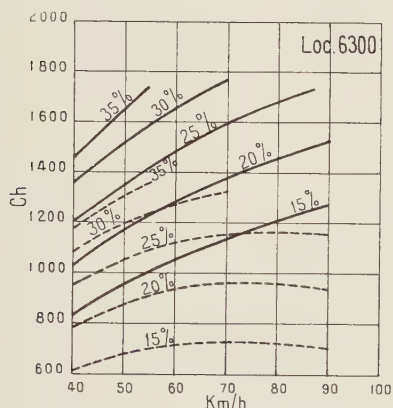


Fig. 52. — Indicated and drawbar horse-power, Netherlands Rys. 6300 locomotives.

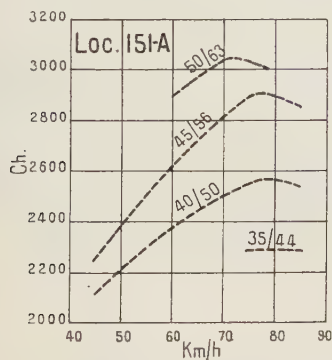


Fig. 54. — Drawbar horse-power, P.L.M. 151.A (2-10-2) locomotives.

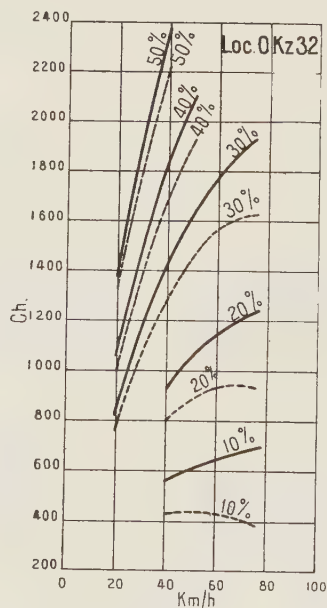


Fig. 55. — Indicated and drawbar horse-power, Polish State Rys. O Kz 32 locomotives.

V. — Heat units used by the engine.

The consumption of heat by the engine is on the average between 4 000 and 5 000 calories (15 870 and 19 840 B.T.U.) per indicated H.P.-hour.

VI. — Thermal and specific efficiency of the engine ⁽¹⁾.

The following table summarises the information received.

This table shows at a glance that the real thermal efficiency of the engine now exceeds 0.15, the specific efficiency exceeding 0.8.

VII. — Efficiency of the motion $\left(\frac{Pe}{Pi}\right)$ and running resistance in kgr./t. of the locomotive and tender as a whole.

It should be noted to begin with,

RAILWAYS.	Type of locomotive.	Working characteristics.		Efficiency.		
		Speed.	Cut-offs.	Actual thermal. (pm)	Theoretical thermal. (pr)	Specific. $\alpha = \frac{mp}{p^T}$
<i>Austrian Federal Rys.</i>	214	...	...	0.11	...	...
<i>Alsace-Lorraine Rys.</i>	S 16	75 km./h. 100 km./h.	...	0.1518 0.161	0.218	0.725 0.74
<i>Est Rys.</i>	241.000	80 km./h. 100 km./h. 120 km./h.	50/60	0.166 0.15 0.14	0.186 0.179 0.169	0.892 0.838 0.84
<i>French State Rys.</i>	231. 644. DD	100 and 120 km./h.	40/70 and 60/70	0.134 to 0.149	0.181 to 0.186	0.74 to 0.80
<i>P. L. M. Rys.</i>	241. C 1 231. H	...	...	0.13 à 0.15 0.155	0.18 to 0.19 0.185	0.74 to 0.86 0.83
<i>P. O.-Midi Rys.</i>	240.700	110 km./h.	...	0.155	0.19	0.80

that the indicators used give *incorrect* results, the amount of error not being exactly known. This is the reason for certain discrepancies on investigations into engine resistance properly speaking and in comparisons between the consumption figures when related to the indicated power.

Consequently we think it desirable

⁽¹⁾ The *specific efficiency* α is the ratio of the true heat efficiency p_m to the theoretical thermal efficiency p_r

$$\alpha = \frac{p_m}{p_r} = \frac{\left(\frac{\Delta \lambda R}{\lambda} \right)}{\left(\frac{\Delta \lambda T}{\lambda} \right)} = \frac{\Delta \lambda R}{\Delta \lambda T}$$

that indicators with not only minimum, but also known, errors should be made available at an early date.

The efficiency of the mechanism $\frac{Pe}{Pi}$ varies with the speed, the admission, and the type of locomotive. Figures 56 and 57 give the efficiency curves of a *Pacific* locomotive and a *Mountain* locomotive. For an indicated horsepower of 3 200 recorded at 100 km. (62 miles) an hour, the efficiency is 0.74 (30 % cut-off) for the *Belgian Pacific*, and 0.68 (45/61 % cut-off) for the *P.L.M. Mountain*.

The following interesting figures we-

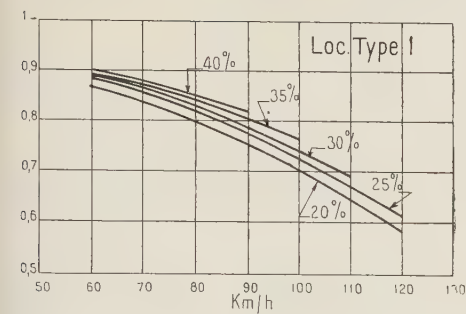


Fig. 56. — Efficiency of the motion in terms of the speed. *Belgian Nat. Rys. Co. type 1 Pacific locomotives.*

re obtained at the Vitry test plant for a 4-8-2 locomotive of the *Est Ry.*, the efficiency being the ratio of the power at the tread of the driving wheels to the indicated power :

Speed. Km./h.	Cut-off, %	P_i (indic.)	P_j (tread).	$\frac{P_j}{P_i}$
60	64/60	2 760 H.P.	2 568 H.P.	0.93
80	60/60	3 204 H.P.	2 894 H.P.	0.90
100	50/60	3 206 H.P.	2 795 H.P.	0.87

A study of the *running resistance* ⁽¹⁾ shows rather divergent results when considering the different values at a given speed in terms of the cut-off.

The *Belgian Rys.* type 1 locomotive, for a given speed shows a remarkably constant resistance when the cut-off is altered from 20 to 40 %.

The *P.O.-Midi Rys.* during tests of their 4-8-0 (701) locomotive found that « though a certain dispersion is observed in the distribution of the experimental points, it has not been possible to deduct any clear law as regards the

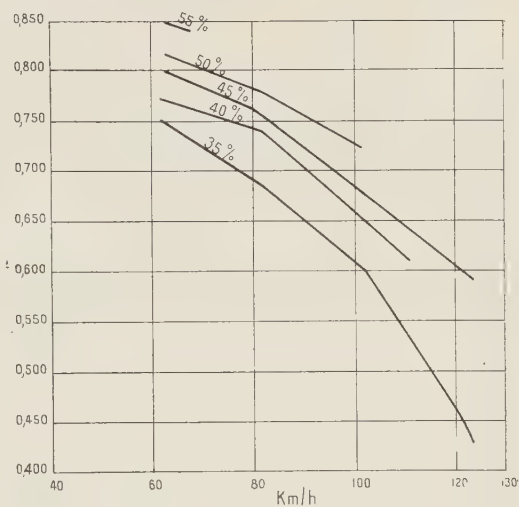


Fig. 57. — Efficiency of the motion in terms of the speed, *P.L.M. 241 C.1 Mountain locomotive.*

influence on the resistance of the locomotive due to the cut-off or the power developed ».

The *Netherlands Rys.* have obtained for the different cut-offs resistance curves parallel and close enough to one another, showing a slight but definite increase in the resistance with the cut-off.

The 4-8-2 C1 *P.L.M.* locomotive gave similar results (fig. 58.)

VIII. — Coal and water consumption per indicated horse-power/hour and per effective horse-power/hour.

The improvement in the modern locomotive is particularly reflected in the consumption figures.

⁽¹⁾ The running resistance considered here is the running resistance with the regulator open, and the locomotive hauling the trial train.

1. Road tests.

(a) *Pacific locomotives.*

The figures obtained are given in the following table :

Railway.	Type of locomotive.	Effective H. P.*	Indicated H. P.	Coal consumption. (kgr.)		Water consumption. (litres.)	
				per effective	per indicated	per effective	per indicated
				H. P./h.	H. P./h.	H. P./h.	H. P./h.
Speed : 100 km. (62 miles) an hour.							
French State.	231.644 DD	2 000	...	1.1	...	8	...
		2 200	...	1.17	...	8	...
P.L.M.	231.H	2 000	2 600	0.9	0.7	7.1	5.45
		2 200	2 800	0.97	0.77	7.1	5.65
P.O.-Midi	231.700	2 000	2 700	0.92	0.68	6.92	5.19
		2 200	2 900	0.93	0.70	6.74	5.12
Speed : 120 km. (75 miles) an hour.							
P.L.M.	231 H	2 000	2 750	1.1	0.8	7.9	5.75
		2 200	3 000	1.13	0.825	7.9	5.8
P.O.-Midi	231 700	2 000	3 000	1.14	0.76	7.95	5.31
		2 200	3 200	1.15	0.79	7.75	5.33

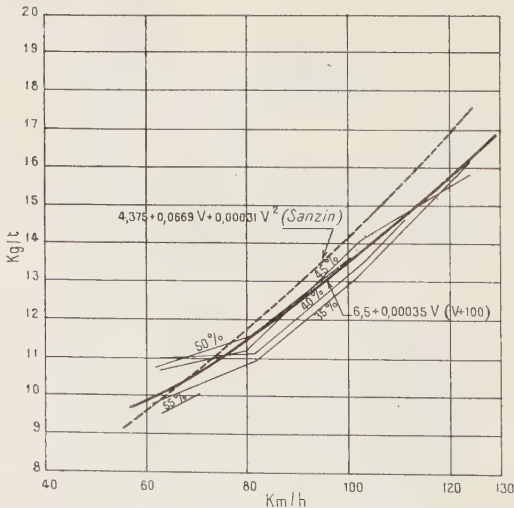


Fig. 58. ~ Running resistance in terms of the speed, *Mountain* type 241.C-1 locomotive, *P.L.M. Rys.*

When the figures of the above table are examined a wide difference [100 H.P. at 100 km. (62 miles) an hour and 200 H.P. at 120 km. (75 miles) an hour] will be observed between the power (Pi-Pe) absorbed by the *P.O.-Midi* and *P.L.M. Pacifics*; this difference affects the calculated figures of the consumption per indicated horse-power (cf. § VII).

(b) *8-coupled locomotives.*

Figure 59 reproduces the consumption curves per effective horse-power/hour of a 240.700 (4-8-0) locomotive of the *P.O.-Midi*.

(c) *10-coupled locomotives.*

Figures 60 and 61 give the consumptions of the *Nord* 5.1200 locomotives and the *P.L.M.* 151-A (2-10-2) locomotives.

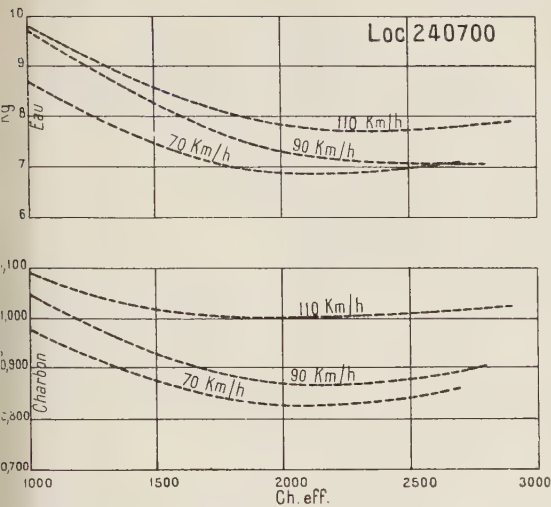


Fig. 59. — Coal and water consumptions per drawbar horse-power/hour, P.O.-Midi 240.700 locomotives.

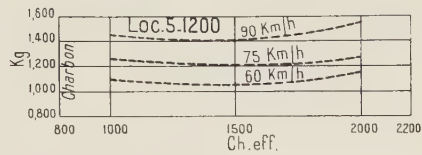


Fig. 60. — Coal consumption per drawbar horse-power/hour, French Nord 5.1200 locomotives.

2. Tests on the testing plant.

Tests carried out at the Vitry testing plant have given the following figures for the consumption per horse-power/hour at the tread of the driving wheels :

Railway.	Type of Locomotive. (<i>Pacific.</i>)	H. P. at the tread.	Consumption per horse-power/hour.	
			Coal.	Water.
		Speed : 100 km. (62 miles) an hour.		
<i>Est</i>	241.400	2 795	0.97 kgr.	8 24 litres.
<i>P.L.M.</i>	231.H	3 032	0.881 kgr.	5.78 litres.
		Speed : 120 km. (75 miles) an hour.		
<i>P.L.M.</i>	231.H	2 924	0.898 kgr.	5.94 litres.

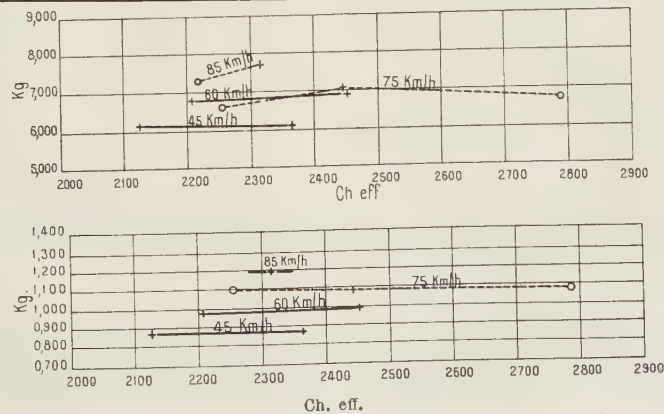


Fig. 61. — Consumptions per drawbar horse-power/hour, P.L.M. 151.A locomotives.

These figures show that at a speed of 100 km. (62 miles) an hour the consumption is 0.7 kgr. (1.54 lb.) of coal and 5.2 l. (1.14 Br. gall.) of water per indicated H.P. hour for an indicated horse-power of 2 800.

The lower and higher calorific values of the coals used by the Railways during these tests, as well as their chemical analysis are given in the table hereafter.

Coal used for the locomotive tests.

RAILWAYS.	Type of fuel.	Contents.			Lower calorific value (calories).	Higher calorific value (calories).	Proportion large coal 80 mm (3 1/8")
		Water. %	Ash. %	Volatile matter. %			
<i>Reichsbahn</i>	" Standard coal "	2.4	5.7	26.28	7200-7700	...	...
<i>Austrian Federal Rys.</i> .	" Standard coal "	2	4	...	7400	...	...
<i>Alsace-Lorraine Rys.</i> .	Ruhr run of mine.	...	5.6	20.24	...	...	100 %
	Screened Sarre.	...	5.6	34.36	...	...	50 %
	Mixture of 50 % run of mine, and 50 % screened.	...	...	...	7800	...	75 %
<i>Est Rys.</i>	...	...	...	...	7722-7877	...	...
<i>French State</i>	Large Aniche.	...	3.9	26.8	...	8205	...
<i>Nord Ry.</i>	Anzin - Cuvinot screened.	...	4.75	23.10	7950	...	...
	Marles 20-80 screened.	...	3.70	36.30	7680	...	...
	...	...	...	...	...	...	...
<i>P.L.M.</i>	Briquettes for lighting up.	1.62	6.99	16.74	8000	8300	...
	Screened coal.	0.83	4.43	22.46			
<i>P.O.-Midi</i>	Large coal.	2.0	4.8	17-19	...	8310	...
	Briquettes.	1.9	7.8	16-18	...	8100	...
	Mixture of 60 % large coal and 40 % briquettes.	...	...	...	7950	8240	...
	...	...	...	...	...	...	...
<i>Hungarian State</i> . . .	Tata 0-150 run of mine.	11.52	9.95	...	...	5379	...
	Washed Pec-Szabolcs, 0-10.	4.37	19.94	...	...	6194	...
<i>Netherlands Rys.</i> . . .	...	...	...	...	7500-7600	...	...
<i>Polish State</i>	Wolfgang mine coal.	...	...	...	7320-7400	...	...
	...	...	...	...	...	...	...

IX. — Overall efficiency (effective and indicated).

At 110 km. (68.3 miles) an hour, values of 0.145 for the indicated efficiency, and

0.093 for the effective efficiency have been reached. Figures 62 and 63 give the efficiency in terms of the power, for different speeds, of a *Pacific* locomotive and an 8-coupled locomotive.

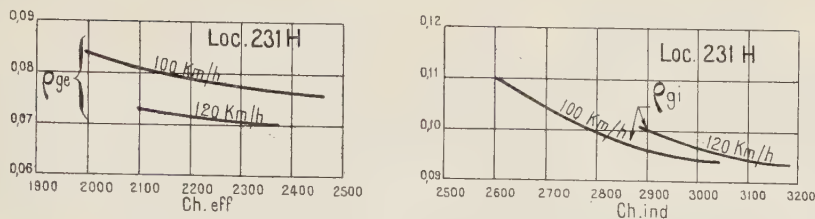


Fig. 62. — Overall effective (ρ_{ge}) and indicated (ρ_{gi}) efficiency, P.L.M. 231.H-141 locomotive.

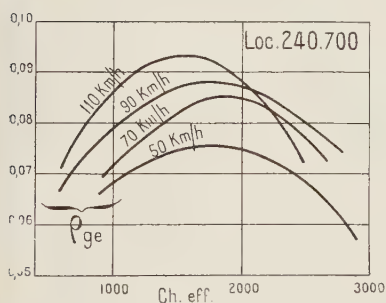
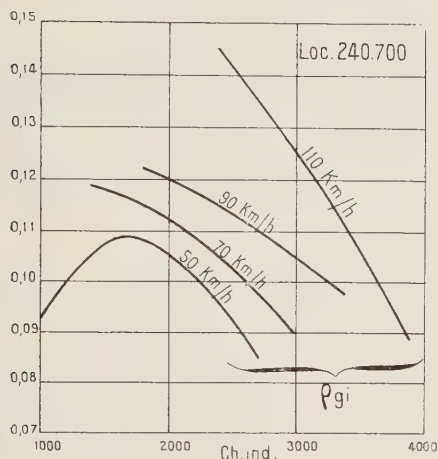


Fig. 63. — Overall effective (ρ_{ge}) and indicated (ρ_{gi}) efficiency, P.O.-Midi 240.700 locomotives.

X. — Summary.

As a result of recent improvements in the locomotives, the specific power and

the efficiency of steam locomotives have been markedly increased. Under certain operating conditions, a figure of 14 % for the indicated efficiency and 9 % for the effective efficiency are being obtained.

* * *

CHAPTER XII.

Use and maintenance of modern locomotives.

I. — Stock.

The high-speed and goods steam locomotives built according to present formulæ only form a relatively small part of the locomotive stock of the Railways. This can also be said of the recently rebuilt locomotives.

II. — Mileages run.

Modern locomotives because of their great power are used in an intensive way.

The annual distance run in former times rarely exceeded 50 000 km. (31 000 miles) ; it now often exceeds 80 000 km. (50 000 miles), and in some cases 100 000 km. (62 000 miles)—(130 000 km. = 80 780 miles on the *Reichsbahn*, and 150 000 km. = 93 210 miles on the *Austrian Rys.*).

III. — Working.

The most widely used method of working is still with a single set of men. There are some cases where two and even three sets of men are used, however.

There are in particular three sets of men on passenger locomotives of types 7 (4-6-0) and 10 (4-6-2) of the *Belgian Rys.* and on the 2-10-2-A goods locomotives of the *P.L.M.*

The *Alsace-Lorraine Rys.* are the only ones on which some of the engines are pooled, but this is only to a small extent.

The *French State Rys.*, at the Thouars and Argentan depots, have workings known as « associated workings ». A certain number of sets of men, always the same, drive a certain number of locomotives, always the same. The number of sets of men is greater than the number of locomotives, without being a multiple thereof : for example 8 sets of men drive 5 locomotives.

The numbers of these various locomotives, the distance they run and the method of working them are given in table XI.

IV. — Distances, tonnages and speeds.

(a) *Maximum distances between change-over points.*

The maximum distances between points at which engines are changed have been increased very considerably thanks to the following measures :

— high-capacity tenders [30, 35 and even 38 m³ (6 600, 7 700 and 8 360 Br. gall.) of water, and 10 tons of fuel];

— water pick-up troughs, such as on the *French State Rys.*, on the Paris-Cherbourg line;

— coal pushers, or even mechanical stokers⁽¹⁾;

— pulverised coal or oil firing (only a

few locomotives have been equipped for trial purposes)⁽¹⁾.

The distance between points at which engines are changed frequently exceeds 300 km. (186 miles).

The Railways have given the following figures for the longest single engine runs :

— *Reichsbahn* : 500 km. = 310 miles;

— *French State Rys* : 412 km. = 256 miles;

— *P.L.M.* : 419 km. = 260 miles (Paris to Clermont) and starting from the 1937 summer services, 511 km. = 318 miles (Paris to Lyons).

In the case of goods services, the longest runs are 200 to 250 km. (124 to 155 miles).

(b) *Maximum distances between stops.*

The maximum distances between stops depend upon the operating conditions. If certain express trains even exceed 200 km. (124 miles), the ordinary express trains run much shorter distances without stopping, owing to the towns being nearer together in densely populated countries. The *Nord Ry.*, for example, reports that its ordinary expresses mostly stop every 15 km. (9.3 miles) which lowers their overall speed, whereas the fastest express trains have a much higher average speed.

As examples of the longest non-stop runs may be mentioned :

— *Est Ry.* : 353 km. = 219 miles (Paris to Nancy);

— *Nord Ry.* : 367 km. = 228 miles (Paris to Liège).

In the case of goods services, the runs are about 100 km. (62 miles).

(1) Cf. Chapter XIV.

TABLE XI

Use of locomotives. — Stock. — Distances covered and trains worked.

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(c) *Weight of trains.*

The improvements in the efficiency of locomotives have made it possible, at a given speed, to increase the weight of the trains. It has also made it possible to raise the classification of certain of the engines; for example, *Pacifics* are able on difficult sections to work relatively heavy trains formerly reserved for 8-coupled engines.

(α) *Weight of passenger trains.*

The type 1 *Pacific* of the *Belgian National Rys. Co.* works 400-ton trains over the Luxemburg line, on which there are long 1 in. 62 gradients.

On the *Est Ry.* the improved 230 000 (4-6-0) locomotive can now work relatively heavy express trains (300 tons).

On the *French State Rys.* the improved *Pacific* locomotives haul 500 tons on the extra fast trains (*rapides*) and 600 tons on the express trains on lines with 1 in 100 gradients.

On the *P.O.-Midi Rys.* the fastest trains hauled by the 231 700 (4-6-2) locomotives are of 450 to 550 tons and even 700 to 800 tons, in the case of express trains with frequent stops, between Tours and St. Nazaire or Bordeaux. The 240 700 (4-8-0) locomotives haul similar tonnages over the difficult Brive and Montauban line, with 1 in 100 gradients. By putting these engines into work the double heading of trains 61, 68 and 78 is avoided, and the weight which formerly was limited to 530 tons is now often 650 to 700 tons.

Finally on the *P.L.M.*, the putting into service of the 231-G (4-6-2) locomotives has enabled the weight of the fastest trains to be increased to 500 tons on the average, and to 600 tons for certain trains.

(β) *Weight of goods trains.*

The weight of goods trains frequently exceeds 1 000 tons on rather difficult roads.

The G.12 locomotives of the *Alsace-Lorraine Rys.* are hauling 1 600-ton trains on the Strasbourg-Remelfing section (92 km. = 57 miles) long at an average speed of 35 km. (21.7 miles) an hour. The 250 000 (2-10-0) locomotives of the *Est*, of similar type, are working trains of an average weight of 1 078 tons.

On the *Nord* the 5.1200 locomotives are hauling coal trains of 2 200 tons between Lens and Le Bourget (212 km. = 131.7 miles) at an average speed of 37 km. (23 miles) an hour.

The 151.A (2-10-2) locomotives of the *P.L.M.* are hauling trains of an average weight of 900 tons at an average speed of 38.5 km. (23.9 miles) an hour over the Laroche-Dijon line which includes the Blaisy gradient.

(d) *Maximum speeds allowed.*

The maximum speeds allowed for steam trains vary on the different railways.

It is 140 km. (87 miles) an hour on the *Reichsbahn*, 120 km. (75 miles) an hour on the *Belgian* and *French* Railways, 110 km. (68.3 miles) an hour on the *Polish* and *Algerian Rys.*, 100 km. (62 miles) an hour on the *Austrian Rys.*, and 95 or 90 km. (59 or 56 miles) an hour on the other Railways.

(e) *Highest average speeds.*

The overall speeds of the express trains on most railways tend to approach 100 km. (62 miles) an hour, and in some cases exceed this figure.

The following table gives a few average speeds.

Administrations.	Run.	Length of run. (km.)	Average weight of trains. (metric tons)	Overall speed. (km./h.)
<i>Reichsbahn</i>	Berlin-Hamburg	286	...	120
<i>Alsace-Lorraine</i>	Mulhouse-Strasbourg	109	...	100.5
	Strasbourg-Metz	155	230	98.5
	 Do	155	350	91
<i>French Est</i>	Paris-Troyes	167	341	103
	Nancy-Paris	353	282	100.5
<i>French State</i>	Paris-Rouen	140	...	101.2
<i>Nord</i>	Paris-St-Quentin	154	...	105
	Paris-Belgian Frontier.	238	...	105
	Paris-Liége	367	...	94
<i>P.L.M.</i>	Paris-Marseilles	862	328	94
	... Do. . . (1937 summer).	862	206	98.5
<i>P.O.-Midi</i>	Tours-Bordeaux	352	300	100.4
	of which Poitiers-Angoulême	113	300	113
	Bordeaux-Tours	352	500	93.2

V. — Maintenance costs per kilometre run.

The modern locomotives on most railways have been in service too short a time for the costs of a complete maintenance cycle to be available. It is therefore impossible to show the effect of recent improvements on the maintenance costs.

VI. — Summary.

1. The distance run without changing engines frequently exceeds 300 km. (186 miles), and even reaches 500 km. (310 miles). The maximum distances between stops exceed 350 km. (217 miles). Finally the overall speeds often exceed 100 km. (62 miles) an hour.

2. High-efficiency locomotives have been in service too short a time for the costs of a complete maintenance cycle to be available. It is therefore not possible to evaluate the effect of the improvements made to these locomotives, on the maintenance costs.

*
* *

CHAPTER XIII.

Streamlining.

The streamlining problem is one of the aspects of the general problem of increasing the power and efficiency of locomotives.

Although the first investigations and the first tests of arrangements intended to reduce the air resistance (1) were made a considerable time ago, it was not until high-speed railcars, running at 140 km. (89 miles) an hour and over, were introduced that the problem of high-speed steam traction was raised again.

I. — Description of streamlined locomotives.

The most complete streamlined locomotives are those of the *Reichsbahn* and the *P.L.M. Rys.* These two Railways

(1) Cf. *P.L.M. Bulletin*, July 1935, p. 95, article by M. PARMANTIER; *Glaser's Annalen*, 1st December 1935, p. 172, article by Herr NORDMANN.

each own several streamlined engines with enclosed tenders or streamlined tank engines, for hauling streamlined trains.

The *Netherlands Rys.* have streamlined one of their 4-6-0 locomotives and its tender.

The *French State Rys.* have streamlined as a trial a 4-6-2 locomotive, the tender of which was only streamlined to some slight extent.

The *Est Rys.* have fitted one locomotive with the arrangement known as the « Huet deflector », intended to create a mass of still air round the engine.

The *Belgian National Rys.*, without streamlining in the true sense of the word their type 1 locomotives, have covered in the dome, feed water heater, and sand box with a casing of ovoid form connected to the cab by inclined

surfaces. The side plates of the tender continue the lines of the locomotive and the form of the whole is not unlike that of a streamlined locomotive.

(a) *Reichsbahn streamlined locomotives.*

The Reichsbahn has built two types of streamlined locomotives: two class 05 4-6-2 engines with separate tender, and a class 61 tank engine of the 4-6-4 type.

(α) *Class 05 locomotive with separate tender (fig. 64).*

The class 05 locomotives were built to haul 250-ton trains at 150 km. (93 miles) an hour. These are three-cylinder simple expansion 4-6-4 engines with separate tenders, and driving wheels 2.30 m. (7' 6 9/16") in diameter. The boiler pressure is 20 kgr./cm² (284 lb. per sq.



Fig. 64. — Class 05 streamlined locomotive, Deutsche Reichsbahn.

in.), and the boiler is of the ordinary type but with the barrel in molybdenum steel; the grate area is 4.70 m² (50.6 sq. ft.). The maximum speed is 175 km. (108.7 miles) an hour (1).

(1) See *Organ* of the 1st February 1936, page 41, article by Herr WAGNER; *Bulletin of the International Railway Congress Association*, December 1935, p. 1437; *Die Reichsbahn*, 6th March 1935, article by Herr FUCHS.

The casing covers the whole locomotive, including the motion, and is brought down to within 0.25 m. (10") of the rails. A large number of inspection doors have been provided in the casing; the largest for getting at the motion are closed by corrugated plate shutters which can be operated quickly. The smoke screens are extended 3.50 m. (11'6") on both sides of the chimney.

The tender is also streamlined, and its lines prolong those of the locomotive. Plates fixed to the cab and supported on the tender by springs prevent any break in continuity between the engine and tender.

The top of the tender is covered in by two moveable plates which slide towards the cab, and so uncover the top of the tender when loading coal.

As it would be difficult for the fireman to get at the coal, two compressed-air pushers are provided in the coal well.

The tender carries 37 m³ (8 140 Br. gall.) of water. It is carried on 5 pairs of wheels, a 4-wheeled bogie at the front

end and 3 independent pairs of wheels at the trailing end.

The *Reichsbahn* owns two locomotives of the 05 class, N^{os} 05.001 and 05.002. The 05.002 has ordinary axle boxes, whereas locomotive 05.001 has roller bearings in its carrying axles and on the tender, an arrangement that will be used on all new locomotives.

(β) *Class 61 tank locomotive and streamlined light train.*

The class 61 locomotive ⁽¹⁾ (fig. 65) is a tank engine designed to run in both directions, and is entirely streamlined.



Fig. 65. — Class 61 streamlined locomotive, *Deutsche Reichsbahn*.

This engine is intended to haul light trains at a maximum speed of 175 km. (108.7 miles) an hour. It is a 2-cylinder simple-expansion engine. The boiler, the pressure of which is 20 km./cm² (284 lb. per sq. in.), like that of the 05 locomotive, is of smaller size: grate area 2.75 m² (29.5 sq. ft.) instead of 4.70 m² (50.6 sq. ft.), and a total heating surface of 152 m² (1 640 sq. ft.) instead of 256 m² (2 755 sq. ft.).

Five water tanks connected by pipes

give a total water capacity of 17 m³ (374 Br. gall.); the coal bunker can hold 5 tons.

The *four-coach light train* built for being worked by this locomotive deserves a special description. Its total weight does not exceed 130 tons, although there

⁽¹⁾ Cf. *Die Reichsbahn*, 12th June 1935 and 15th January 1936, article by Herr FUCHS; *Bulletin of the Railway Congress*, July 1936, p. 753.

are 192 second and third-class seats. The connection between the locomotive and the train is not streamlined, but those between the coaches are. In order to reduce air resistance, the foot boards of the coaches fold up into the body sides and are lowered in the stations.

The train includes a restaurant and kitchen, a luggage compartment, and mail compartment. It is electrically lighted, and air conditioned, each coach being ventilated and heated by air blown

in with 3 ranges of temperatures automatically regulated.

(b) *P.L.M. streamlined locomotives and trains* (1).

Unlike the streamlined stock of the *Reichsbahn*, which is new, the locomotive and train of the P.L.M. consists of existing stock streamlined after alteration (fig. 66).

The 221.A (4-4-2) locomotive chosen has 2 m. (6'6 3/4") driving wheels, such

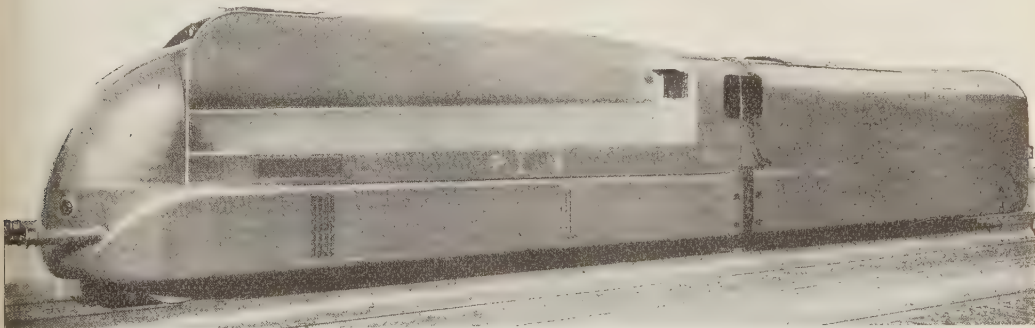


Fig. 66. — Class 221.B (4-4-2) streamlined locomotive, P.L.M. Rys.

engines, built in 1907, having shown themselves particularly suitable for high speeds. To increase the power of the engine, it was superheated, and an efficient P.L.M. blast pipe and an A.C.F.I. feed water heater fitted. The locomotive was covered in with a casing completely enclosing the motion and coming down to within 0.35 m. (14") from the rails, with a number of inspection doors. Screens connected to the rest of the casing and completed by inclined planes on each side of the chimney prevent the smoke beating down, without increasing the air resistance.

A 30-m³ (6 600 Br. gall.) tender of the kind used with high-speed locomotives was also streamlined entirely down to the same level as the locomotive, and the top provided with two sliding doors controlled from the cab, and covering in the coal bunker.

The roof of the locomotive cab is connected by a canvas cover to the casing of the tender. The back of the latter is coupled up to the train without any gap, by an indiarubber bellows.

The locomotive and tender are fitted with electric light.

A rake of ordinary stock was streamlined. It consists of 4 standard coaches carried on S.K.F. roller bearing boxes: a 1st-class carriage (48 seats), two 2nd-class (144 seats), and a composite restaurant-brake vehicle. The lower part of these carriage was streamlined, an inspection door being provided opposite each axle.

The indiarubber bellows prevent any break in continuity between the coa-

(1) Cf. *Revue Générale des Chemins de fer*, December, 1935, page 373, article by M. PARMANTIER.

ches. Each end of the rake has been given a streamlined shape, as far as was compatible with coupling the train to the tender.

The railway now has two streamlined locomotives and one rake of stock. Five other locomotives and three other trains are being converted, and one will be air conditioned for trial purposes.

(c) *French State Rys. streamlined locomotives.*

The French State Rys. have streamlined a *Pacific* locomotive with Dabeg oscillating cam gear on the low pressure cylinders (fig. 67). The streamlining leaves the motion uncovered. The side screens have been removed and are now attached to the casing. Various parts

(feed heater, air pump) have been streamlined individually.

The tender has only been streamlined in a rough and ready way; but more complete streamlining is under investigation.

The *French State Rys.* are looking into the streamlining of the 230,000 (4-6-0) locomotives.

(d) *Streamlined locomotive of the P.O.-Midi Rys.*

The *P.O.-Midi Rys.* have just streamlined one of their 231,700 *Pacific* locomotives.

(e) *Streamlined locomotives of the Netherland Rys.*

The *Netherlands Rys.* have streamlined



Fig. 67. — *Pacific* type streamlined locomotive, *French State Rys.*

one of their 4-6-0 locomotives. Figure 68 shows the general form of the casing, which leaves the motion partly clear. Inspection doors are provided. The tender is also streamlined.

(f) *Est locomotive fitted with a Huet deflector.*

The *Est Rys.* have fitted a Huet deflector to a 4-6-0 locomotive.

The arrangement tested consists of

plates at the front end of the locomotive, intended to keep a mass of still air round the locomotive, over which air currents, which otherwise would come into contact with the locomotive, would be deflected as by a metal casing.

With the Huet deflector, the side screens, which do not interfere with this formation of a mass of still air, have not to be removed. Figure 69 shows the arrangement on a 4-6-0 *Est locomotive.*



Fig. 68. — 4-6-0 type streamlined locomotive, *Netherlands Rys.*

II. — Special arrangements adopted for running at very high speeds.

(a) Diameter of the driving wheels.

With locomotives of the classic type and Walschaerts valve gear, there is no doubt that the driving wheels should be very large.

The *Reichsbahn* has built new locomotives for running at 175 km. (108.7 miles) an hour with 2.30 m. (7' 6 9/16") diameter wheels.

The other Railways, who have only *rebuilt* their locomotives, have selected locomotives with 2 m. (6' 6 3/4") dia-

meter wheels. These engines are not likely to be called upon to exceed 140 or 150 km. (87 to 93 miles) an hour in ordinary working.

The speeds of rotation obtained are 374 r. p. m. on locomotives with 2-m wheels, at 140 km. an hour, and 404 r. p. m. on locomotives with 2.30-m. wheels at 175 km. an hour.

(b) Lightening the parts of the motion.

The various Railways have endeavoured to lighten the motion parts in order to reduce the inertia effects.

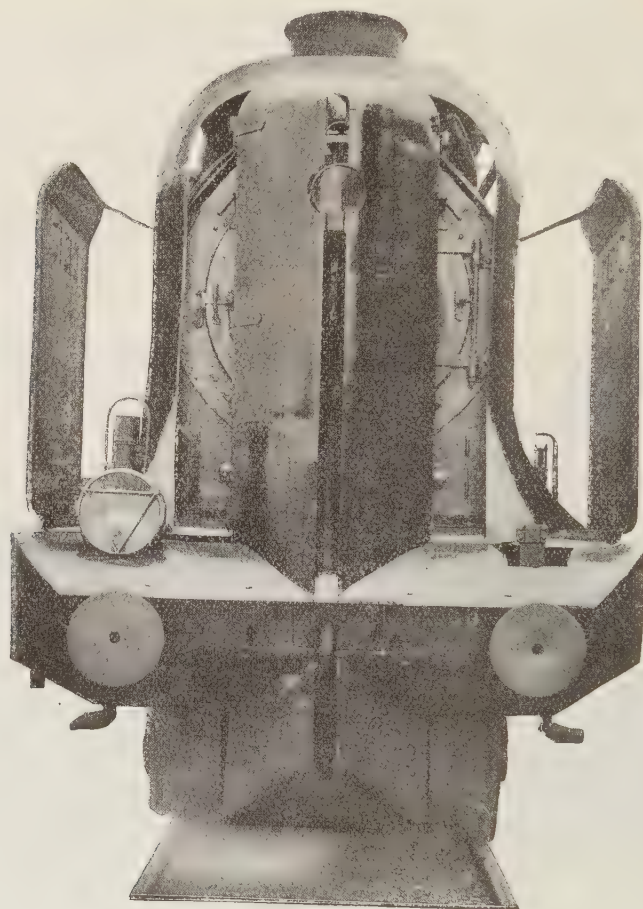


Fig. 69. — French Est 230.000 locomotive with Huet deflector.

On its 05 locomotives the *Reichsbahn* has used pressed steel pistons. The connecting rods are I sections and the centre of the crank axle has been drilled out in order to reduce the weight.

The modified *P.L.M.* locomotives have been fitted with the lightened piston valves described in Chapter VIII.

(c) Method of using the steam.

The *Reichsbahn* has retained simple expansion with two cylinders on the 61 class tank engines, and three cylinders

on the class 05 locomotives. These two types of locomotives are equipped with bar frames.

The *French Rys.* have selected for alteration 4-cylinder compound locomotives.

(d) Lubrication.

High-speed running involves very careful lubrication of the motion, and this can only be done mechanically.

On the 05 locomotive the parts in contact with the steam and the inside slide

bars are lubricated by means of two high-pressure *Bosch* pumps with 20 feeds. Lubrication of the 221.B locomotives of the P.L.M. is by means of two *Bourdon* mechanical lubricators, one with 24 feeds for the motion, and the other with 9 feeds for the cylinders and air pump.

III. — Brake gear.

In order to be able to stop within the regulation distance, the rolling stock in trains intended to run at high speed has had to be equipped with suitable brake gear. It has been necessary to substitute, for the braking at constant pressure, a brake the pressure of which varies with the speed. The variation may be continuous (*Westinghouse*, *Piganeau*, and

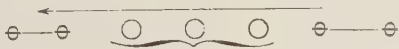
Jourdain-Monneret), or discontinuous (*Reichsbahn*).

1. Description of the arrangements and applications.

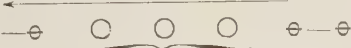
(a) *Reichsbahn* brake (1).

The streamlined locomotives are fitted with a *centrifugal regulator* driven by one of the axles (tender axle in the case of the 05 locomotives) which at a given speed (about 50 km. = 31 miles an hour) alters the air pressure in the brake cylinders from 6.5 to 2.7 kgr./cm² (92.4 to 38.4 lb. per sq. in.).

In this way, on the 05 locomotives the following coefficients of braking are obtained :

	Locomotive.							Tender.				
												
V > 50 km/h .	50	80	180	180	180	180	180	180	180	180	180	180
V < 50 km/h .	50	80	75	75	75	75	75	75	75	75	75	75

In the case of the class 61 tank locomotive, the coefficients are :

						
50	80	180	180	180	180	112

In addition, this locomotive being reversible, it is fitted with a means of reversing the distribution of the braking power as between the bogies, when the running direction is altered.

The brake blocks of the 05 locomotive are all in two sections, and in order to reduce the specific pressure still further, each wheel has two blocks, with the exception of the first pair of wheels of the locomotive bogie which has only one. In view of the small space between the driving wheels, as well as between the 3 trailing pairs of wheels of the tender, the brake blocks could not be placed on the horizontal centre line.

Figure 70 shows the arrangement adopted.

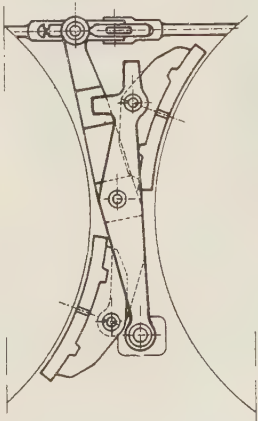


Fig. 70. — Arrangement of driving wheel brake blocks on class 05 locomotives, *Deutsche Reichsbahn*.

(1) Cf. *V.D.I.*, 12th October 1935, p. 1244, article by Herr RECKEL .

The locomotive tender, in addition, has a brake the power of which varies with the weight of water.

The brake equipment of the vehicles hauled by the 05 class locomotives includes, in addition, a *Knorr twin accelerator* which gives the braking wave a speed of propagation of 800 to 1 000 m. (2 620' to 3 280') per second, and a *quick filler* for the brake cylinders, which device only acts in cases of emergency applications.

The vehicles of the rake hauled by the class 61 tank locomotive have been given the special disc brakes of the *Bergische Stahl Industrie*. This brake includes vertically arranged jaws which act on the discs secured to the wheel centres. They are applied either by double brake cylinders or by a hand-operated wheel. Figure 71 shows this equipment. In addition the bogies are fitted with a magnetic brake.

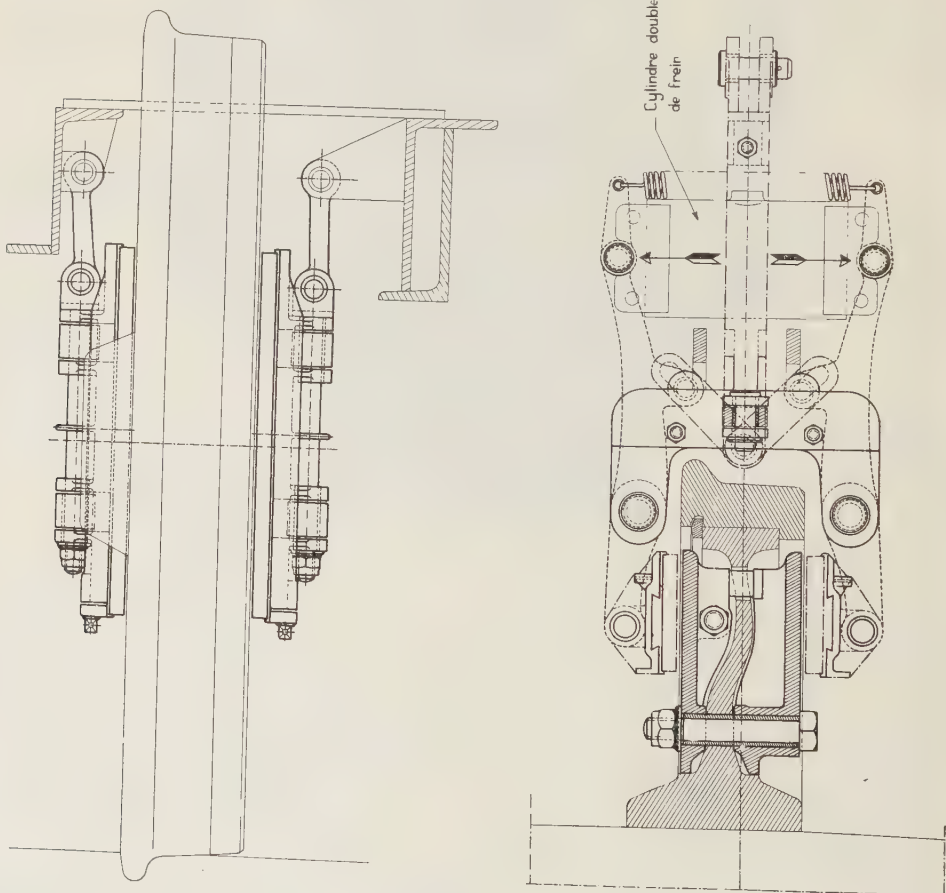


Fig. 71. — *Bergische Stahl Industrie* disc brake on the streamlined train of the *Deutsche Reichsbahn*.

(b) *Westinghouse, Piganeau and Jourdain-Monneret devices.*

The *Westinghouse, Piganeau and Jourdain-Monneret* devices are characterised by the fact that the centrifugal regulator driven mechanically by an axle creates a braking pressure constantly varying with the speed.

In the *Westinghouse system* the normal cylinder can be duplicated by an additional cylinder the power of which can be added to that of the normal cylinder when necessary, or the standard cylinder can be fed directly with air at a pressure varying with the speed.

The admission of air to the additional cylinder or to the single cylinder is controlled by the centrifugal regulator.

The *Jourdain-Monneret* brake acts on a principle similar to that of the variable *Westinghouse* brake.

In the *Piganeau system* the centrifugal regulator acts directly on the air brake gear to which it adds its power. It receives its movement from a roller which, when the brake is applied, is caused to engage with a pulley keyed on one of the axles by a cable operated by the brake gear.

After long tests, the P.L.M. Rys. have decided to equip half their streamlined locomotives and rakes with the *Westinghouse* brake, and half with the *Piganeau* brake.

The brake pressure is limited to the usual value with constant pressure braking when the speed is below some 40 km. (25 miles) an hour; this value increases in terms of the speed, and is doubled at about the maximum speed of 140 km. (87 miles) an hour.

The locomotives are also equipped with the *Westinghouse device for braking in proportion to the weight of water.*

The third and fifth pairs of wheels

of the locomotive ⁽¹⁾ and the tender and carriage wheels of the streamlined stock are also fitted with double brake blocks.

The *French State Rys.* have also been equipping their fast trains with the variable power brake.

The *Est*, on the other hand, has under test auto-variable braking and load braking.

The *P.O.-Midi Rys.* have under test, on a carriage, the *Jourdain-Monneret* auto-variable brake.

2. Braking distances obtained.

(α) *Reichsbahn* arrangement.

Brake tests with the 61 class locomotive and the *streamlined* rake have given at 165 km. (102.5 miles) an hour, on 1 in 500 down gradients a stopping distance of 860 m. (940 yards).

With the ordinary rakes of stock, by fitting double brake shoes it was possible to stop a train of 24 pairs of wheels (corridor vehicles on 2 bogies), hauled at 130 km. (80.8 miles) an hour by an S10 locomotive and braked at 180 %, in 650 m. (710 yards) on the level.

Finally the braking distance required to stop the 05 locomotive by itself was 1 050 m. (1 148 yards), from 160 km. (100 miles) an hour.

(β) *Westinghouse and Piganeau systems.*

Brake tests carried out by the P.L.M. with two identical trial trains (1 streamlined 4-4-2 locomotive and 4 carriages), one train equipped with the *Westinghouse* automatic brake and the other the *Piganeau* automatic brake, gave much the same results.

(1) The P.L.M. Rys. owing to lack of space, have not been able to use double brake blocks on the other wheels of the locomotive.

The table below gives some of the figures obtained :

Brake.	Brake blocks.	Braking distances and times.			
		Speed 117 km./h., 1 in 400 gradient.		Speed 140 km./h., 1 in 200 gradient.	
		Distance.	Time.	Distance.	Time.
Ordinary brake by itself.	single	764 m.	42 s.	1 230 m.	58 s.
	double	722 m.	39 s.	1 128 m.	53 s.
Ordinary brake in conjunction with self-regulating brake.	single	591 m.	33 s.	930 m.	43 s.
	double	524 m.	28 s.	840 m.	39 s.

This table shows that the gains obtained on the braking distances are :

— 8 % when double brake blocks are used instead of single, with the same braking (either ordinary or auto-variable).

— 24 % when the ordinary brake is replaced by the auto-variable brake, at high speeds with single blocks.

— 30 % when auto-variable braking with double shoes is resorted to in place of ordinary braking with single shoes.

In practice on a down gradient of 1 in 200, at a speed of 140 km. (87 miles) an hour :

— double brake blocks save 100 m. (109 yards) on the stopping distance ;

— the special brake saves 300 m. (327 yards) on the ordinary brake ;

or a total gain of 400 m. (436 yards).

Finally *Westinghouse* or *Piganeau* auto-variable brakes acting on double shoes make it possible to stop a train of 4 vehicles running at 140 km. (87 miles) an hour on a down gradient of 1 in 200 in a distance definitely shorter than the present 1 000-m. (1 090 yards) distance at which signals are placed from the point they have to protect.

Figure 72 reproduces the curves obtained by the *P.L.M. Rys.* when stopping from 140 km. (87 miles) an hour.

IV. — Tests carried out in wind tunnels.

Most of the Railways have carried out tests of streamlined locomotives in wind tunnels with small-scale models.

In order to take into account the influence of the ground over which an actual train moves, the « double model » method is frequently used. This consists of suspending two identical models symmetrically about a fictive plane representing the ground and measuring the resistance of the whole. The resistance of the model supposed to be near the ground, is then taken as being half the value obtained.

M. Roy ⁽¹⁾ has shown the difficulties of interpreting such tests which, if the actual resistances are to be obtained quantitatively from the results in the wind flume imply the existence of two conditions :

(a) absolute similitude of the forms and movements ;

(1) Cf. *Revue Générale des Chemins de fer*, January 1933, page 3; *Bulletin of the Railway Congress*, August 1933, p. 738.

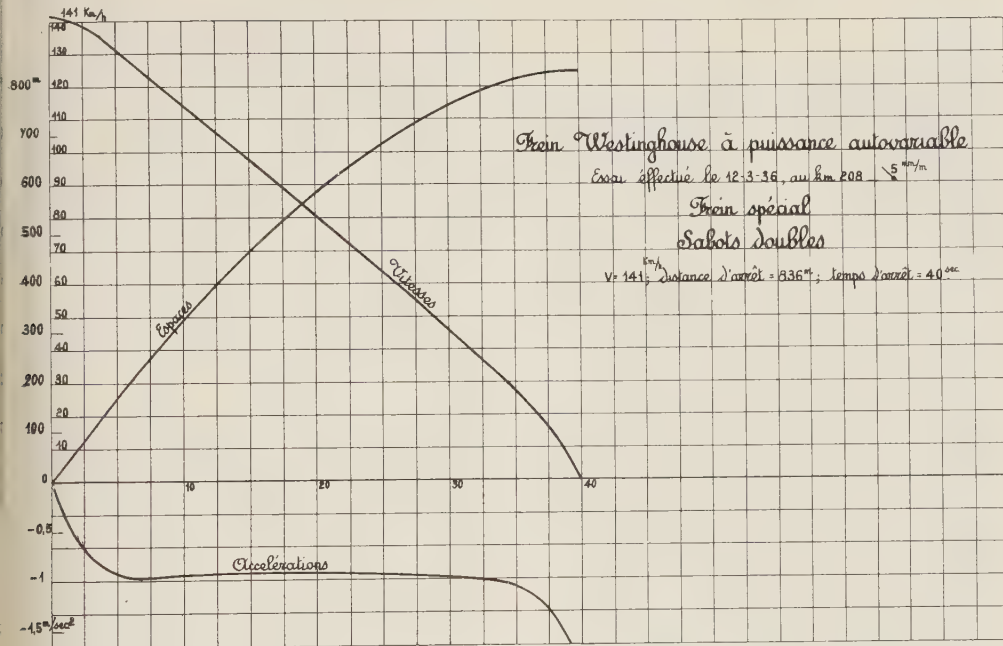


Fig. 72. — Braking curves of P.L.M. streamlined train.

Explanation of French terms:

Espaces = distances. — Vitesses = speeds. — Frein Westinghouse, etc... = Westinghouse auto-variable power brake. Test carried out on 12th March 1936, at km. 208, on a 1 in 200 down gradient. Special brake. Double blocks. Speed 141 km./h. Stopping distance 836 m. Stopping time 40 seconds.

(b) identity of the corresponding Reynolds numbers ⁽¹⁾.

Condition (a) has not been obtained so far owing to the existence of the ground, the double model method only giving a very rough approximation.

Nor has condition (b) been met so far. As very small scale models have to be used, especially when dealing with a whole train, to get identical Reynolds numbers speeds of the air current are required which are not possible at the present time. In existing wind tunnels speeds of 150 to 200 km. (93 to 124 miles) an hour represent the maximum.

The result of these divergencies is to « under-estimate, probably to a large extent, the theoretical factors relatively to the real ».

The tests carried out in 1934 ⁽²⁾ in the air tunnel of the New York University on models of steam trains and rail motor trains, confirmed the inaccuracy of the double-model method. During these tests, an endeavour was made to represent more exactly the presence of the ground by an endless belt moving under the model at the speed of the air current. In this way an exact repre-

(1) The Reynolds number is the ratio of the product of the speed by a length characteristic of the vehicle to the kinematic viscosity of the fluid.

(2) Cf. The *Railway Mechanical Engineer*, December 1935, page 496, article by Messrs. DE BELL & LIPETZ.

sentation of the relative speeds has been obtained.

There is, however, no representation of the obstacles on the ground, particularly meeting the sleepers at regular intervals. This explains why the stopping of the endless belt did not alter the results obtained, which led the American experimenters to operate with a fixed floor.

Wind tunnel tests are valuable, however, when qualitative results only are desired, and it is desired to ascertain the best profiles.

The American tests have shown in particular the value on streamlined locomotives of making the front end in the form of the crest of a helmet, of completely enclosing the motion and bogies of the vehicles hauled, and of providing a suitable tail end for the rake.

The *P.L.M.* tests showed the necessity of cutting away the bottom part of the tail end to release the air fillets compressed between the track and the frame.

(a) *Tests on the Reichsbahn.*

These were undertaken, in the same spirit, to determine the best form of streamlining, first of all in the wind tunnel at the Berlin Higher School on models of 1/33 scale, then in the Göttingen tunnel on 1/20 scale models. It was

found that in the case of standard locomotives, the hemispherical smoke box and vee'd cab sides only gave a slight improvement. Encasing the motion diminished the resistance appreciably, but to obtain a large reduction the locomotive must be completely encased, the casing being brought down as near as possible to the rails. The best result was obtained with a streamlined tank engine with the cab at the front end.

The result of these tests is seen in the streamlining of the 05 and 61 locomotives.

From the quantitative point of view, these tests in the wind tunnel show that properly streamlining a tank engine should save 570 H.P. at 150 km. (93 miles) an hour and 750 H.P. with a violent side wind.

(b) *French State Rys. tests.*

The French State Rys. carried out a whole series of tests in the wind tunnel of the St. Cyr Aerotechnical Institute on a 1/10 scale model of the 4-6-2 locomotive, in order to study the effect of the different elements of streamlining and of side winds.

From the results obtained in the wind tunnel they obtained the following figures for the power absorbed by the actual locomotive in calm air :

Speed.	Ordinary engine with side screens.	Ordinary engine without side screens.	Engine streamlined at front end.	Engine completely streamlined.
120 km./h. . .	339 HP	386 HP	262 HP	231 HP
150 km./h. . .	663 HP	560 HP	512 HP	452 HP

This table shows how full streamlining saves 108 H.P. at 120 km. (75 miles) an hour, and 211 H.P. at 150 km. (93 miles) an hour.

The test with side wind gave :

—	Side wind at 20 km./h.			Side wind at 60 km./h.		
	Head.	Perpen- dicular.	Rear.	Head.	Perpen- dicular.	Rear.
	<i>HP.</i>	<i>HP.</i>	<i>HP.</i>	<i>HP.</i>	<i>HP.</i>	<i>HP.</i>
<i>Engine with ordinary side screens</i>	462	450	236	763	345	85
<i>Streamlined engine</i>	315	245	160	520	145	58
<i>Gain in power</i>	147	105	76	243	200	27

During the tests the *State Rys.* measured the lateral force of the wind at 60 km. (37.3 miles) an hour on an engine running at 120 km. (75 miles) an hour. The maximum force was found with a wind direction of 65° with the centre line of the engine, and the calculation gave for an actual engine a force of 1 700 kgr. (3 750 lb.) on the non-streamlined locomotive and 1 800 kgr. (3 970 lb.) on the streamlined locomotive.

V. — Tests on the line.

1. Maximum speeds.

The maximum speed of the 05 locomotives of the *Reichsbahn* reached the remarkable figure of 200.4 km. (124.5 miles) an hour. With a load of 250 tons this locomotive maintained on the level a speed of 175 km. (108.7 miles) an hour, and reached on several occasions 190 km. (118 miles) an hour.

2. Effect of streamlining the motion.

The *Reichsbahn* carried out on a 03 locomotive, the motion of which was encased, a series of tests at 140 km. (87 miles) an hour, which showed on the one hand that the temperature of the boxes and big ends was not much higher than on an ordinary locomotive, and on the other hand that enclosing the motion saved 150 to 200 H.P. at 140 km. an hour.

As a result of these trials the 05 and 61 locomotives have been built with the motion cased in. To ventilate the motion and increase at the same time the access of air to the ash pan, the casing of the lower part of the 05 locomotive has been cut away slightly at the front end.

The 221-B locomotives of the *P.L.M. Rys.* have been streamlined in the same way. Ventilating shutters, as can be seen in figure 66, have been provided on the right and left sides of the locomotive.

These two Railways have not met with any difficulties, so far, as a result of enclosing the motion. Tests in the wind tunnel and on the line show that there is an appreciable increase in power through this arrangement, so that there is every advantage in streamlining the engines in future.

3. Gain in power.

(a) *Reichsbahn tests.* — The road trials of the 05 locomotive No. 002 show that streamlining this engine saved 500 H.P. at 160 km. (100 miles) an hour.

The *Reichsbahn* proposes to carry out with an 03 (4-6-2 type) streamlined locomotive further tests on the line and in the wind tunnel.

(b) *P.L.M. tests.* — The *P.L.M. Rys.* have carried out a whole series of trials

to ascertain as accurately as possible the gain due to streamlining. In order to reduce the variable effect of the atmospheric conditions to the minimum, the tests were carried out as rapidly as possible, which led to the use of two sets of identical stock, the only differences between which were in the streamlining, namely :

— the streamlined locomotive, and a locomotive of the same type which had been improved in the same way but not streamlined ;

— two rakes of stock, one streamlined and the other not, each composed of 4 identical vehicles, one of which was an O.C.E.M. dynamometer car.

The object of the tests was to ascertain the power saving relatively to a whole train not streamlined, with :

— a whole streamlined train ;

— a streamlined locomotive and a non-streamlined rake ;

— a non-streamlined locomotive and a streamlined train.

The *P.L.M.* carried out the following tests :

(α) Trials of the two locomotives at the Vitry test plant to compare the locomotives one with the other and to ascertain the correspondence of the cut-offs at which the indicated H.P. would be the same at each speed.

(β) Tests of the two locomotives at constant speed, with brake locomotive and dynamometer car to determine the variation in the resistance of the air on the locomotive and tender.

(γ) Comparative trials at high speed over a long distance of trains made up of one of the two locomotives and one of the two rakes of 4 vehicles, to ascertain on the one hand the variation of the air resistance of these rakes, and on the other the saving of fuel and water due to streamlining.

The results of these series of tests are

summed up in the form of curves in figures 73 and 74.

In the case of a 4-coach train, at 140 km. (87 miles) an hour, streamlining saves :

— 450 H.P. when the train is entirely streamlined ;

— 260 H.P. when only the locomotive is streamlined ;

— 90 H.P. when only the rake is streamlined.

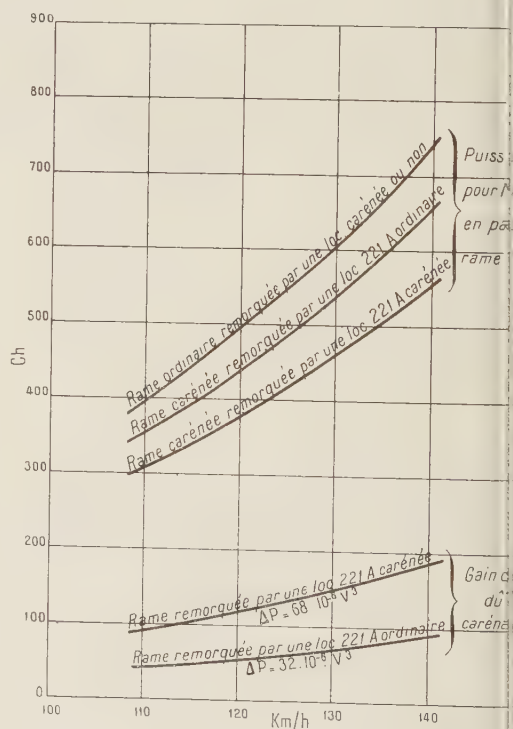


Fig. 73. — Power required to haul on the level a train of 200 tons. Saving in power due to streamlining (*P.L.M. Rys.*).

Explanation of French terms :

Rame ordinaire... = rake of ordinary stock hauled by an ordinary engine. — Rame carénée... = streamlined rake hauled by an ordinary (a streamlined) 4-4-2 engine. — Puissance nécessaire... = power required to haul a train of 200 tons on the level. — Gain de puissance... = gain in power due to streamlining of the train.

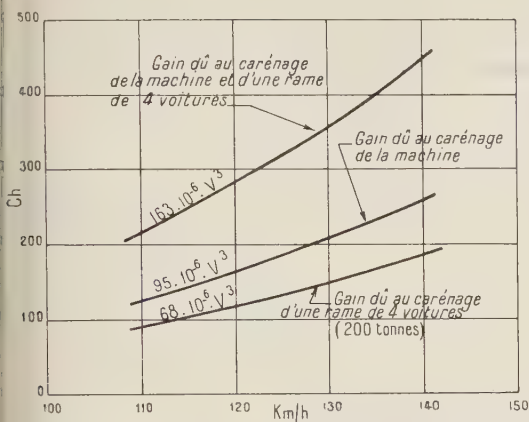


Fig. 74. — Power saved by streamlining the stock: 4-4-2 P.L.M. locomotive with a 30-m³ tender, hauling a rake of 4 bogie steel carriages.

Explanation of French terms:

Gain dû au carénage de la machine et d'une rame... = saving due to streamlining the engine and rake of 4 carriages. — Gain dû au carénage d'une rame... = saving due to streamlining a rake of 4 vehicles.

(c) *Tests on the Netherlands Rys.* — Running tests with the 4-6-0 type streamlined locomotive showed at 120 km. (75 miles) an hour, a saving of 100 effective H.P.

(d) *Tests on the Est Rys.* — During tests on the line, at constant speed, of the locomotive fitted with the Huet deflector, the *Est* endeavoured to eliminate the effect of variations in the atmospheric conditions. For this purpose they used the « witness locomotive » process. A locomotive as like as possible to the locomotive to be tested, runs behind the latter at a few minutes interval, under the same running conditions; the variations in power of the witness locomotive make it possible to ascertain the corrections that have to be made in the results given by the locomotive being tested, in order to take into account atmospheric variations.

Tests carried out with this method have shown that the Huet deflector sa-

ves 100 H.P. at 110 km. (68.3 miles) an hour on an engine fitted with side screens intended to prevent the smoke beating down.

4. Fuel saving.

Tests carried out by the P.L.M. on long runs have shown the coal consumption per kilometre to be :

8.9 kgr. of coal and 70.7 litres of water for a non-streamlined train ;

6.4 kgr. of coal and 54.3 litres of water for the streamlined train, which shows a saving of 28 % of fuel and 23 % of water.

Taking the annual mileage of the locomotive as 100 000 km. (62 150 miles), the 2.5 kgr. saving of coal represents an annual saving of 250 tons per locomotive, or 32 500 francs on a 130 fr. per ton basis.

VI. — Summary.

Streamlining of locomotives and trains reduces appreciably the air resistance at high speed ; it enables locomotives of old types to be retained, which if not streamlined would not be powerful enough to reach and maintain the high speeds required.

* * *

CHAPTER XIV.

Miscellaneous.

I. — Special steels and light alloys.

1. Special steels.

(a) *Special steels used to lighten the parts of the motion.*

Special steels for lightening the motion have not been used on a very wide scale. Some Railways even tend to give up using them, especially for axles.

The following table gives particulars of the special steels used for parts of the motion by the various Railways.

Railways.	Class of locom.	Parts.	Kind of metal.	Specification.
<i>Austrian Federal</i> . . .	214	Connecting rods. Crank pins.	Nickel-manganese steel. Nickel-chrome steel.	... ...
<i>Alsace-Lorraine</i> . . .	S 16 and G 16	Crank pins. Piston rods.	Nickel-chrome-molybdenum steel.	After heat treatment oil-hardened at 850° C. and tempered at 625° C. Elastic limit ≥ 70 kgr./mm ² Tensile str. ≥ 85 kgr./mm ² Elongation ≥ 13 % Resilience 8 kgrm. on standard V.F. test pieces.
<i>Est Rys</i>	...	Connecting rods. Coupling rods.	Nickel-chrome steel of S. D. quality.	S.T.U. Nos. 130 and 187.
		Crank axles.	Nickel-chrome steel (SF quality).	S.T.U. Nos. 130 and 187.
		Valve gear rods.	Nickel-chrome steel (SB and SF qualities).	
		Piston heads.	Nickel chrome cast steel.	
<i>Nord Ry.</i>	3.1200	Driving axles (high-pressure and low-pressure).	Nickel-chrome steel.	S.T.U. Nos. 130 and 187.
	4.1200	Connectings rods and coupling rods.	Nickel-chrome steel (SF quality).	

On the French Rys. special forging steels meeting the S.T.U. No. 130 specification are classified in 4 groups :

- Nickel steels mild, case hardened . . . — SB quality.
- Nickel-chrome steels
 - semi-mild, case hardened . . — SD quality.
 - semi-hard — SF.
 - hard, self-hardening . . . — SH.

The chemical composition must meet the following conditions :

Quality.	Minimum nickel. %	Minimum chrome. %	Maximum phosphorus. %
SB	2.0	...	0.04
SD	2.5	0.5	0.04
SF	2.5	0.5	0.04
SH	3.5	1.25	0.04

The mechanical tests must give the following results :

Quality.	Minimum tensile strength. kgr./mm ² .	Minimum elongation. o/o	Minimum resilience in kgrm./cm ² . of section.
SB	48	22	20
SD	60	18	15
SE	75	13	10
SH	90	10	5

Nickel or nickel-chrome steel axles in service on the *Est*, *Nord* and *P.L.M.* Rys. have caused these Compagnies considerable trouble owing to the formation of numerous cracks on the journals and crank pins and alterations in the metal as soon as overheating started. The *P.L.M.* has abandoned axles containing nickel for a number of years ; the *Est* and *Nord* in their turn are giving them up and returning to the use of carbon steel.

The *Est Ry.* is also returning to the use of D steel for the rods that it formerly made in nickel-chrome steel. On the other hand, piston heads in cast nickel-chrome steel have been satisfactory, behaving better, being lighter and costing less.

Generally speaking the sheds do not repair parts in special steels. These repairs, and in particular heat treatment, are exclusively carried out in the main workshops.

The railways have not given any detailed information on the weight saved by using special steels for motion parts.

The *Alsace-Lorraine Rys.* state they save 30 kgr. (66 lb.) per connecting rod with chrome-nickel-molybdenum steel on the S.16 and G.16 locomotives.

The *Est* states that no appreciable saving must be counted on as « in order to take into account the range of tensile strengths due to heat treatment, it is ne-

cessary to use a higher factor of safety than with other steels ». The experience of this Railway has made it doubt the success of the heat-treatment. The steels when properly heat treated are undoubtedly better than the ordinary steels, but there is never any certainty that the treatment has been properly carried out.

The *Reichsbahn* is equally sceptical. Rather than use special steels to save weight, it prefers to improve the cross section of the rods and piston heads.

(b) *Use of special steels in the frame and boiler, to reduce the dead weight.*

(α) *Boiler.* — The use of nickel steel in boiler plates, and in particular in the barrel, tends to become general with the use of high pressures. This is so on the *Alsace-Lorraine*, *P.L.M.* and *Algerian Rys.* The *Alsace-Lorraine Rys.* use a 2 % nickel steel with tens. of ≥ 45 kgr./mm² (28.6 Engl. tons per sq. in.), $E \geq 25$ % and Mesnager resilience of 20 kgrm. in the horizontal direction. The *P.L.M.* uses on its 20 kgr./cm² (284 lb. per sq. in.) pressure boilers a steel to the following requirements :

1. Nickel : 3 % $\pm$ 0.3 %.

2. Mechanical tests—on test pieces of the type defined in the standard specifications :

- (a) Tensile test $\left\{ \begin{array}{l} \text{El. lim.} \geq 30 \text{ kgr./mm}^2 \text{ (19.05 Engl. tons per sq. in.)}; \\ \text{Tens.} \geq 50 \text{ kgr./mm}^2 \text{ (31.75 Engl. tons per sq. in.)}; \\ \text{Minimum elongation, \% measured on a} \\ \text{length between gauge points, of} \\ \sqrt{66.67 S : E} \geq 20 \% \\ \Sigma^{(1)} = 0.5. \end{array} \right.$
- (b) Bend test $\left\{ \begin{array}{l} \text{Ends brought parallel with an opening} \\ \text{of } 3e \text{ (as the plates are delivered).} \end{array} \right.$

3. Viscosity tests at 210° C. (400° F.) on test pieces of square section with sides equal to the thickness of the plate, and 100 mm. (4") long between gauge points.

Heating in an electric furnace, between the jaws of an Amsler machine; application of a load of 21 kgr./mm² (13.33 Engl. tons per sq. in.) for one hour. After complete cooling the permanent elongation found shall not exceed 0.2 mm. (0.0079 in.).

(β) *Frame*. — The bar frames of the S.16 and G.16 locomotives of the *Alsace-Lorraine Rys.* are made of steel containing 2 % nickel, with Tensile strength $\geq 45 \text{ kgr./mm}^2$ (28.6 Engl. tons per sq. in.), Elongation 25 %, and a Charpy resilience of 12 to 14 kgrm.

The *Est* have under test a number of box girder frames made of vanadium cast steel.

Finally the cylinders of the class 5.1200 locomotives of the *Nord Rys.* are in cast steel of the ES quality with Tens. $\geq 55 \text{ kgr./mm}^2$ (34.9 tons per sq. in.), and $E \geq 15 \%$ (S.T.U. No. 12).

(c) *Use of special steels for springs*.

The *Reichsbahn* uses for its locomotive springs M, E or B crucible steel of homogeneous composition, which can be hardened in water :

Breaking strength after annealing at 810° C. (or 30° above the point of transformation) : $\geq 85 \text{ kgr./mm}^2$ (54 Engl. tons per sq. in.).

(1) This notation designates the ratio of the reduced area at the moment of breaking to the original area of the tensile test piece.

Elongation $\geq 12 \%$ measured on 200-mm. (8") test pieces (2).

Breaking strength (hardened steel) $\leq 140 \text{ kgr./mm}^2$ (89 Engl. tons per sq. in.).

Elastic limit $\geq 110 \text{ kgr./mm}^2$ (69.8 Engl. tons per sq. in.).

Elongation $\geq 5 \%$ measured on 200-mm. (8") test pieces (2).

The temperatures obtained during the heat treatment must be as follows :

Hardening : 820 to 850° C. (3).

Maximum temperature of the water bath : 60° C.

Tempering temperature : 470 to 520° C.

The analysis should show the following percentages :

Carbon	0.40 to 0.55 %
Silicon	1.50 to 1.80 %
Manganese	0.50 to 0.75 %
Phosphorous and sulphur	0.05 % maximum of each.

The *Est Rys.* also have under test springs in chrome-silicon steel. The *Nord Ry.* uses *Apso* metal (copper steel) for the draw-gear springs between the engine and tender.

The *Finnish* and *Polish* State Rys, use springs made of silicon steel.

Finally the *Austrian Federal Rys.* use for poppet valve centering springs, chrome vanadium steel.

(2) In the case of short tensile test pieces this value is increased by 20 % .

(3) When treating steel by means of baths at fixed temperature (temperature of fusion) the lower limit of temperature is used owing to the great heat transmission.

2. Light alloys.

The use of light alloys is still very limited.

The *Alsace-Lorraine* Rys. on their S.16 and G.16 locomotives and the *Nord* on its 5.1200 locomotives are using cross head shoes of class A.S. aluminium alloys, meeting the S.T.U. No. 68 specification.

These details which reduce the weight considerably, [60 kgr. (132 lb.) per cross head on the *Alsace-Lorraine*], have given satisfaction so far (on the *Alsace-Lorraine* up to the 1st May 1936 the mileage was 100 000 km. = 62 000 miles).

The *Est* Rys. are testing piston heads and connecting rods in forged duralumin on some 2-6-2 locomotives, and also forged duralumin connecting rods on some 2-8-2 locomotives. These parts have behaved satisfactorily so far.

II. — Mechanical appliances for loading coal.

1. Coal pushers.

Coal pushers of various types are in use or under test on the tenders of some of the Railways.

(a) Description.

The pushers are driven either by steam (usually) or by compressed air (*Reichsbahn*). They all consist of a cylinder with a piston and rod attached to the pusher element, the reciprocating motion being controlled by an air or steam distributing valve (fig. 75).

(b) Applications.

The following table is a summary of the applications :

Railways.	Type of locomotive.	Capacity of tender.	Number fitted.
<i>Reichsbahn</i>	0 5 streamlined.	37 m ³	2
<i>Est</i>	241 000	35 m ³	14
<i>French State</i>	241 000	35 m ³	49
<i>P.L.M</i>	231	30 m ³	1
<i>P.O.-Midi</i>	240	26 m ³	12
<i>Algerian Rys.</i>	231-132 BT	...	12

(c) Appreciation.

The *French State* and *P.O.-Midi* Rys. are satisfied with the working of the coal pushers ; the *Est* and *P.L.M.* Rys. have not sufficient experience to give any opinion.

2. Mechanical stokers.

The « Standard Stoker » appliance is the only one reported.

(a) Description.

The mechanical stoker consists of a worm driven by a horizontal two-cylinder steam engine, which takes the coal from a hopper in the bottom of the coal bunker and conveys it forward to the grate, after having broken up the largest bits on a crushing plate. A jet of steam distributes the fuel as it is fed into the firebox.

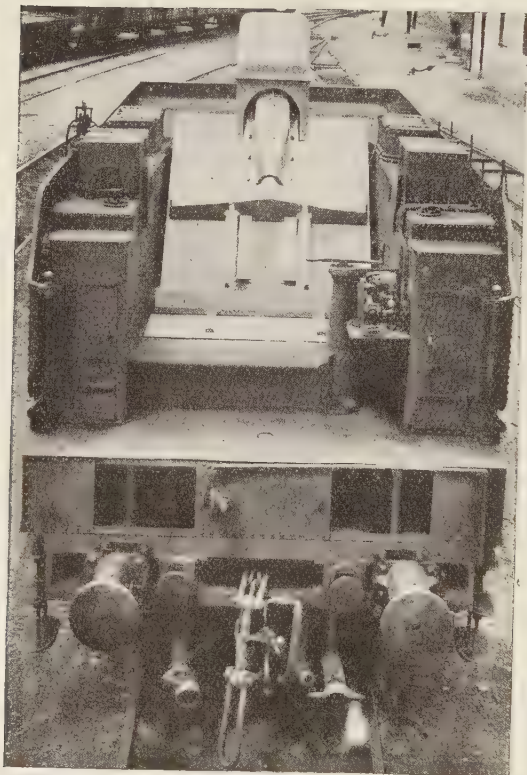


Fig. 75. — FB coal pusher fitted on P.L.V. 30-m³ tender.

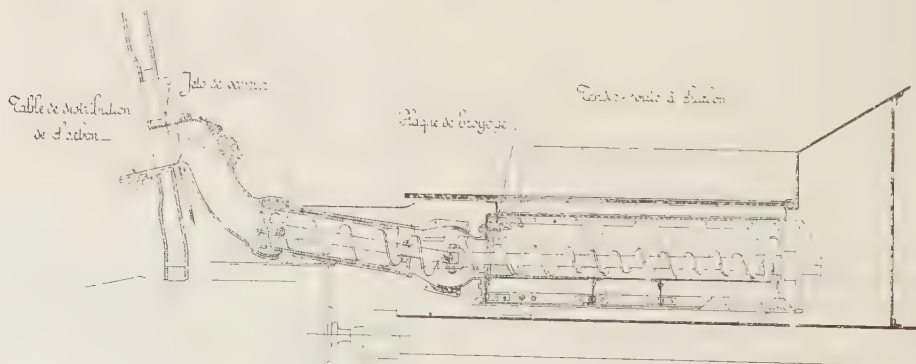


Fig. 76. — BK mechanical stoker fitted on a *Pacific* locomotive, *Nord Ry.*

Explanation of French terms:

Table de distribution... = coal spreader plate. — Jets de vapeur = steam jets. — Plaque de broyage = crushing plate. — Tender... = tender coal bunker.

(1) The *Nord Ry.* uses with the stoker the *Hulson* grate (cf. Chapter III).

In the MB type the conveyor passes under the foundation ring and feeds through the grate. In the BK type, on the contrary, the coal is lifted to the firing door hole and distributed through it which simplifies fitting the equipment.

Figure 76 shows the application of the BK type mechanical stoker to a *Nord* 4-6-2 engine (1).

(b) Applications.

The *French State Rys.* have one 4-8 locomotive (241.101) with 5 m² (57 sq. ft.) grate area, equipped with an MB type stoker.

The *Nord Ry.* has provided a *Pacific* locomotive with 4.27 m² (45 sq. ft.) grate area with a type BK stoker, and two 5.1200 locomotives with 3.48 m² (37.4 sq. ft.) grate area.

(c) Tests carried out and results obtained.

The tests carried out by the *Nord* show that with a thin layer of fuel, coal very rich in volatile gases can be burned without making too much smoke.

The tests have not shown any reduction in the consumption of fuel.

3. Revolving coal bunkers.

The *Algerian Rys.* have tested on a 4-6-2—2-6-4 AT-1 locomotive a revolving type of coal bunker, which was removed owing to excessive vibrations at high speeds.

III. — Oil-fired boilers.

Only two Railways (the *French State* and *P.O.-Midi Rys.*) own engines with oil-fired boilers.

The *Reichsbahn* and the *Austrian Federal Rys.* have fitted an auxiliary oil burner on a few of their coal-fired locomotives.

1. Description.

The equipments on the *French State* and *P.O.-Midi Rys.* consist of three burners with mechanical pulverisation by oil pressure on the *Pillard* system, consisting of :

1 lighting-up burner, the output of which is regulated by varying the pressure of the fuel ;

2 running burners, the output of which can be adjusted by varying the oil pressure and by variation in the sections of the passages through which the oil is fed.

The burners are arranged in the fire door hole, in the middle of the air admission (fig. 77). The lighting-up burner is in the centre and the other burners one on each side.

The installation also includes :

1. An oil tank in the tender ;

2. A pumping and regulating set which includes a horizontal oil pump, an air bottle regulating the supply of oil, an oil preheater (by means of steam), and oil filters.

The grate of these locomotives is replaced by a bed of refractory bricks, the arch is lengthened, and the sides and front walls of the firebox under the arch are lined with refractory material.

2. Locomotives equipped.

The *French State Rys.* have equipped 6 locomotives :

Two Pacifics,

One 2-8-0,

Two 2-6-2 suburban tank engines,

One 0-8-0 shunting engine.

The *P.O.-Midi Rys.* have equipped for trial purposes one 2-8-2 locomotive.

The *Reichsbahn* has equipped, as a trial, a passenger locomotive with auxiliary firing, and the *Austrian Federal Rys.* have ten 2-4-2 tank locomotives for hauling light passenger trains equipped with two Hardy type oil burners mounted on the fire hole door, making it possible to fire with coal and oil.

3. Trials carried out.

The Railways have carried out various consumption tests on the line.

The *French State Rys.* had difficulty in getting the blast right. A variable blast pipe of good efficiency appears to be necessary. Tests are in hand with the Lemaitre blast pipe.

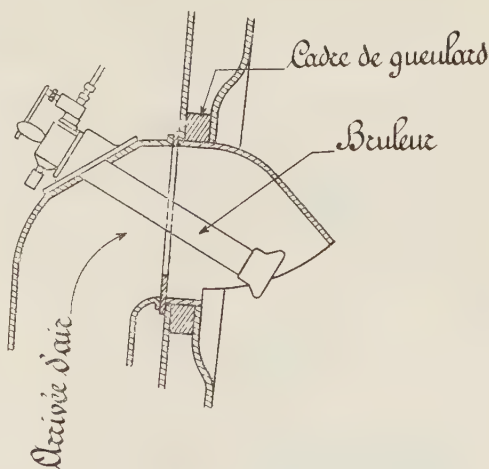


Fig. 77. — *Pillard* oil burner fitted on a *P.O.-Midi* locomotive.

Note : Arrivée d'air = air inlet. — Cadre... = Firehole ring. — Brûleur = burner.

The *P.O.-Midi Rys.* think that the main difficulty is in regulating the air supply round the burners so as to get perfect combustion with a range of 100 to 200 kgr. (220 to 440 lb.) of oil per hour in a firebox of relatively small volume.

During tests with a *Pacific*, equipped for oil burning, the *French State Rys.* obtained a production of 18 tons of steam per hour.

The *P.O.-Midi Rys.* have carried out a road test at a constant speed of 90 km. (56 miles) per hour with an oil-fired locomotive. They obtained an hourly production of 20 tons of steam with 1 980

kgr. (4 365 lb.) of oil, representing 325 kgr. of oil per m³ (546 lb. of oil per cu. ft.) of firebox per hour. The heat efficiency of the boiler was 0.75. The oil used, heavy fuel oil, is given in the standard specification No. 181.

4. Comparison with coal firing.

(a) *French State Rys. tests.*

The *French State Rys.* have carried out comparative trials at the Vitry plant with a 2-8-0 locomotive. They used 2 qualities of coal and 3 qualities of oil, the particulars of which are given in the following analysis :

—		Durham, run of mine.	Aniche, screened.
Coal . . .	Humidity, %	1	0.3
	Ash, %	8.99	5.77
	Volatile matter, %	26.4	22.28
	Carbon, %	78.1	83.32
	Upper calorific value	7552 cal.	7962 cal.

—		Light.	Medium	Heavy.
Oil. . .	Density at 15° C	0.902	0.9103	0.9611
	Barbey fluidity at 20° C	77	46	11
	Luchaire flash point	85.5°	93.5°	107°
	Water content, %	0.25	0.8	0.1
	Cinder content, %	0.017	0.03	0.02
	Carbon content, %	86.83	91.6	87.62
	Hydrogen content, %	12.6	8.1	11.1
	Upper calorific value, calories	10 733	10 675	10 416
	Lower calorific value, calories	10 051	10 233	9 816

The table below gives the values of the ratio :

$$\frac{VH}{VC} = \frac{\text{Weight of water evaporated per kgr. of oil}}{\text{Weight of water evaporated per kgr. of coal}}$$

Characteristics of the trials.	Speed.	20 km./h.						40 km./h.			
	Power at the tread.	500 H.P.		750 H.P.		950 H.P.		500 H.P.		750 H.P.	
Coal with which each fuel oil is compared.		Aniche	Durham	Aniche	Durham	Aniche	Durham	Aniche	Durham	Aniche	Durham
Light fuel oil . . .		1.376	1.539	1.413	1.626	...	...	1.420	1.555	1.340	1.482
Medium fuel oil. . .		1.348	1.508	1.386	1.673 (1)	1.471	...	1.303	1.428	1.264	1.398
Heavy fuel oil . . .		1.232	1.378	1.309	1.506	...	...	1.267	1.388	1.240	1.371

The *French State Rys.* have drawn the following conclusions from these tests :

(α) whatever the coal with which the fuel oil is compared :

— the maximum ratio $\frac{VH}{VC}$ is obtained

$$\text{Average values.} \left\{ \begin{array}{l} \frac{\text{light oil}}{\text{ANICHE coal}} = 1.39 \\ \frac{\text{medium oil}}{\text{ANICHE coal}} = 1.34 \\ \frac{\text{heavy oil}}{\text{ANICHE coal}} = 1.26 \end{array} \right.$$

with light fuel oil, and

— the minimum ratio with the heavy fuel oil.

(β) The ratio $\frac{VH}{VC}$ does not vary much, whatever the quantity of fuel burnt :

$$\begin{array}{l} \frac{\text{light oil}}{\text{DURHAM coal}} = 1.55 \\ \frac{\text{medium oil}}{\text{DURHAM coal}} = 1.44 \\ \frac{\text{heavy oil}}{\text{DURHAM coal}} = 1.41 \end{array}$$

(γ) The theoretical efficiency is slightly higher in the case of oil firing, especially with light and medium oils.

(δ) This advantage would appear to be due to the elimination of losses due to unburnt fuel, rather than to improved combustion by a reduction of the CO.

The *P.O.-Midi Rys.* agree with this latter opinion.

(b) *Tests by the German and Austrian Rys.* (combined firing).

The results obtained by the *German*

(1) The power at the tread during the test was 780 H.P. (instead of 750 H.P.).

and *Austrian Rys.* are not very encouraging. The *Reichsbahn* thinks that oil firing is of little value, as equal evaporation can be obtained with coal firing.

The *Austrian Federal Rys.* found that oil firing was twice as costly as with the best coal.

IV. — Pulverised-coal-fired boilers.

1. Description.

So far tests have been made by two Administrations only, the *Reichsbahn* and the *Royal Hungarian State Rys.* They have used : the former the arrangement designed by the Pulverised Coal

Firing (1) Company (*Stug*), and the latter the equipment of the *Allgemeine Elektrizitätsgesellschaft* (A.E.G.) (2).

Investigations of these two types were carried out in Germany and took rather a long time.

The principal difficulty consists in getting complete combustion of the mixture of air and powdered coal before going through the tubes. In addition combustion leaves a solid residue which has to be sufficiently cooled off before it gets to the tubular plate otherwise it will adhere to it and choke the tubes. It is consequently necessary to have a very careful mixture of the air and coal dust (primary air and secondary air).

The solutions put forward by the *Stug* and A.E.G. are very much like one another. The coal dust contained in a steel tank is brought forward by a worm.

The primary air supplied by a fan picks up the powdered coal at the end of the conveyor. The secondary air

drawn in by the exhaust flows into the firebox under the arch.

The grate is done away with; the walls and bottom of the ashpan are lined with refractory material.

The two arrangements differ mainly by the arrangement of the burners.

2. Locomotives equipped.

The *Reichsbahn* has mounted the *Stug* equipment on 6 class 58 goods locomotives of the 2-10-0 type. These locomotives have been in use for several years.

The *Royal Hungarian State Rys.* have equipped two goods locomotives of the 324 class, 2-6-2 type.

3. Trials carried out.

The *Reichsbahn* has carried out comparative tests at constant speed (40 km. = 25 miles an hour) with locomotives of the 58 class, equipped with *Stug* or A.E.G. equipment, or coal fired.

The results obtained were the following:

	AEG.	Stug.	Coal.
Consumption of steam per H.P./h. (minimum value).	7.5	8.2	8.5
Temperature of superheat for an evaporation of 60 kgr./m ² /h.	406	390	376
Efficiency of the boiler (maximum value and minimum value).	81-74	77.5-75	77.5-70
Maximum H.P.	1475	1440	1360
Consumption of coal per H.P./h. (kgr.)	1.28	1.36	1.08
Calorific value of the fuel	5 200 cal. (lignite).	5 200 cal. (lignite).	7 000 cal.

(1) Cf. *Zeitung des Vereines Deutscher Eisenbahnverwaltungen*, No. 31, (1932) article by Herr F. WITTE.

(2) Cf. *Zeitung des Vereines Deutscher Eisenbahnverwaltungen*, No. 31, 1932, and *Glaser's Annalen*, 15th February and 1st March 1928.

Compared with firing on a grate, for equal rates of evaporation, the superheat temperature is higher, the efficiency of the boiler is greater, and the maximum power of the locomotive is increased.

In addition, the technical advantages expected from firing with pulverised coal have been obtained; possibility of using inferior fuel, easy regulation of the steam production, less work for the staff.

The *Hungarian State Rys.* report, however, a blocking of the tube plate and of the tubes, which have to be cleaned more frequently. The *Reichsbahn* has equipped its locomotives with a sand-jet soot blower.

The latter Railway also noticed on the copper fireboxes in use corrosion of the staybolt heads and the firebox walls. Satisfactory results were obtained by replacing the copper firebox by a mild steel firebox with drifted stays of J. Z. steel.

4. Comparison with ordinary coal firing.

The above table shows the thermal advantages of firing with pulverised coal. The German locomotives equipped were put into service in 1930 and 1931. The balance-sheet for these two years shows on both systems a ratio of the consumption of lignite to that of coal equal to 1.6 on the average, whether the consumption be related to the distance run or to the tonnage.

In both cases the economies on the total traction costs, including maintenance of the locomotive, vary from 6 to 12 %.

5. Financial balance-sheet and conclusions.

According to the two Railways, the pulverised coal firing problem can be considered as solved from the technical point of view.

The *Reichsbahn*, with locomotives so equipped in regular working, reports that the pulverised coal effects a saving in operating costs. In order to get out the

complete balance-sheet it would be necessary to take into account not only the price of lignite, but also the first cost and maintenance of the equipment (on the locomotive and in the depots). The use of this method of firing on a large scale would necessitate not only locomotive equipments but also fixed installations for the mechanical preparation of the fuel and its storage, installations which were not considered during the trials.

The *Royal Hungarian State Rys.* consider that firing with pulverised lignite would only be of advantage when used on a large scale.

V. — Summary.

1. The use of special steels has only been extended slightly.
2. Light metals are practically not used.
3. Some railways are testing coal pushers and mechanical stokers.
4. Tests of oil firing and pulverised coal firing are very limited.

* * *

PART TWO.

Steam locomotives of new types.

The only railway to build a locomotive of new type since 1930 is the *Grängesberg Oxelösund Co.* (turbine locomotive). The *Reichsbahn* is redesigning its turbine locomotives and the various *French Railways* have under construction or under consideration several interesting locomotive types.

We have considered it simpler and more convenient to classify these various types according to the type of engine (piston or turbine), rather than according to the type of boiler.

* * *

CHAPTER X.

Piston locomotives of new types.

The table below gives the characteristics of piston locomotives of new types.

I. — Locomotives with high-speed engines.**1. Winterthur locomotives.**

The *French Nord Ry.* has placed an order with the « Société Suisse pour la construction de Locomotives et de Machines » for one 4-6-2 type locomotive on the *Winterthur system* (1).

Fig. 78 is a section of this locomotive.

(1) Cf. *Bulletin of the Railway Congress*, January 1929, page 75, article by M. BUCHLI, and April 1930. Report No. 3 on Question V, Madrid Congress (1930), page 1259.

The boiler pressure is 60 kgr./cm² (853 lb. per sq. in.).

Each of the three driving pairs of wheels is driven by two groups of 3 cylinders, arranged on both sides of the locomotive and carried on small outside frame bars. The motors are horizontal high-speed engines; working in simple expansion they are double acting and uniflow. The valve gear consists of poppet valves, single seated, driven by rotary cams.

The engines are reversed by auxiliary oil engines.

The three pistons of each engine drive a shaft the cranks of which are at 120° to one another. On each axle the driving shafts, to the right and to the left, are connected by a shaft with an elastic pinion wheel with springs.

The power is transmitted to the axle through gears and a hollow shaft by

Characteristics of the engines.	Ordinary description of the locomotive.	Owning Company	Type of locomotive.	Maximum speed. km./h.	Diameter of driving wheels. m.	We
						Total. Metr. tons
A. High-speed engines . . .	<i>Winterthur.</i>	French Nord.	4-6-2	130	1.550	115
	<i>Bugatti.</i>	French State. P.-L.-M.	8-8-0 8-8-0	150	0.760 0.760	80 80
	<i>Dabeg.</i>	French State.	4-4-0	...	1.250	67.700
B. Direct drive . . .	<i>Schmidt.</i>	P.-L.-M.	4-8-2	110	1.800	114.470
	<i>Velox.</i>	P.-L.-M.	4-6-0	120	2.000	74.400
C. Combined engines . . .	<i>O.C.E.M.</i> Triple expansion.	...	4-6-4	130	1.900	131

means of the « Winterthur universal drive ».

The whole of the drive is carried in an oil tight crank case, the lower part of which forms an oil reservoir, and is lubricated under pressure.

The locomotive is expected to develop 2 000 draw-bar H.P. at 120 km. (75 miles) an hour, and 2 400 at 80 km. (50 miles) an hour. Its normal maximum speed will be 130 km. (80.8 miles) an hour.

The locomotive will be streamlined.

2. Bugatti streamlined locomotives and trains.

(a) P.L.M. locomotive and train.

The P.L.M. ordered from Messrs. Bugatti a streamlined steam train for very-high speed, of lighter construction than the ordinary stock.

This train, consisting of 3 coaches, will be hauled by a locomotive with two

bogies, 4 driving axles, a separate engine on each pair of wheels, and a separate tender.

The water tube boiler is fitted with 2 steam collectors (1 upper collector and 1 lower collector), a steam superheater and air preheater.

The power is supplied by 3 engines of the automobile type, each of 250 H.P., with 8 cylinders in line.

The engine is condensing.

(b) French State locomotive and train.

The French State also ordered a similar locomotive and train from the same builder, the only differences between it and that of the P.L.M. being as follows :

— the power of the locomotive is only one half ; the locomotive has only four 250-H.P. engines which drive four of the

Boiler.			Engine.							Locomotive	
Type	Pressure, kg./cm ²	Kind of fuel.	Ratio of number of r. p. m. of engine to r. p. m. of driving wheels.	Number of engines.	Number of cylinders per engine.	Total number of cylinders.	Diameter of the cylinders.	Piston stroke.	Arrangement of the cylinders.	With or without condenser.	In service, under construction, or projected.
tubes.	60	Coal.	1.975	6	3	18	150	255	Horizontally, in line.	With-out.	Under construction.
tubes.	50	Oil.	1.00	4	8	32	125	130	Vertically, in line.	With.	Under construction.
			1.00	8	8	64	125	130			
ary.	20	Coal.	...	1	12	12	200	280	V-type.	With-out.	Projected.
ary it, boiler iler.	110 60 14	Coal.	1.00	2 HP. 2 LP.	1	4	240	650	Ordinary.	With-out.	Locomotive withdrawn from service in April 1933.
							560	700			
tubes.	20	Oil.	1.00	2 HP. 2 LP.	1	4	370 540	650 650	Ordinary.	With-out.	Boiler being applied to an existing locomotive.
ary.	25	Coal.	H.P. 2.14 M.P. 2.14 L.P. 1.00	2 HP. 2 MP. 2 LP.	1 1 1	6	290 390 680	400 400 680	Side by side, horizontally. Ordinary.	With-out.	Projected.

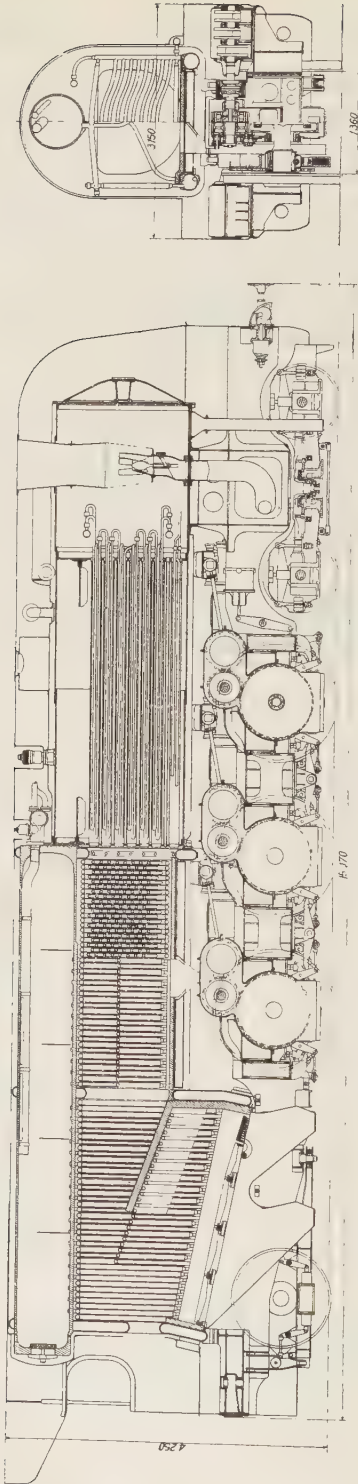


Fig. 78. — Wintherthur system locomotive, French Nord Ry.

pairs of wheels. The other four pairs of wheels are carrying wheels;

— the locomotive is a tank engine.

3. Dabeg locomotive.

The French State has under construction a tank engine of the 4-4-0 type of a new system designed by the *Dabeg* Company (fig. 79).

The boiler, of the classic type, with a pressure of 20 kgr./cm² (284 lb. per sq. in.) provides steam to an engine consisting of 12 cylinders arranged in V on the longitudinal centre line of the engine, above the bogie.

The crank shaft, prolonged by a longitudinal shaft drives hollow axles round the two driving axles through worm gears enclosed in gear boxes.

a) Engine.

The 12-cylinder V-engine is single acting and uniflow. There is only one admission valve per cylinder, the exhaust taking place through ports uncovered by the piston towards the bottom dead centre.

The crank shaft has six throws and 4 bearings, each throw having 2 connecting rods side by side.

The moving parts are arranged in a crank case of cast steel which acts as a cross stay between the frames, in the position normally occupied by the inside cylinders of an ordinary locomotive. This crank case carries the bearings of the crankshaft, the bores for the cylinder linings, and finally the exhaust passages and pipes.

The lower part of the engine is closed by a cast steel crank case which acts as an oil reservoir and carries the bogie pivots.

Each group of 2 cylinders forms an independent unit.

The valve gear is fitted on the front end of the engine.

The motor is expected to develop

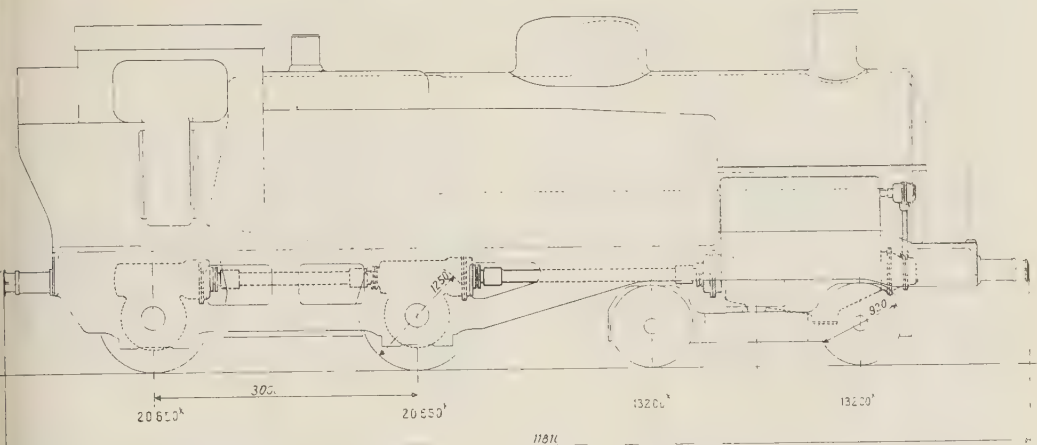


Fig. 79. — Dabeg system locomotive, French State Rys.

1 000 H.P. at 1 200 r.p.m. with about 5 % cut-off.

(b) Drive.

The drive from the hollow axles to the wheels which are in the form of a cross is by a new device with 2 moving frames (fig. 80).

The vertical movement is ± 30 mm. ($1 \frac{3}{16}$ "') with an inclination of $\pm 30^\circ$. The side movement is ± 80 mm. ($3 \frac{5}{32}$ "').

The helicoidal gear, the worm gear and the quill bearings are contained in an enclosed case carried on one of the cross stays of the frame.

c) Lubrication.

The lubrication is by means of a pump on the dry sump principle. The oil pumps are driven by a small auxiliary steam engine and the output is independent of the speed of the locomotive.

II. — Locomotives with direct drive.

1. Schmidt locomotive.

The P.L.M. Ry. built a very-high pressure locomotive, the 241-B-1 (4-8-2) (1) locomotive, of the Schmidt type, already described in the reports to the Madrid Congress (2).

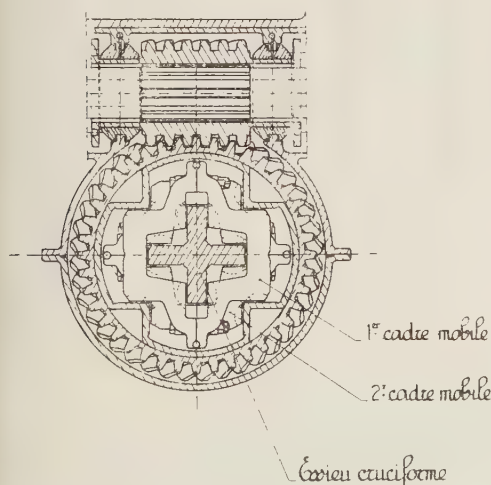


Fig. 80. — Axle drive of Dabeg system locomotive.

Note: 1er (2e) cadre mobile = first (second) mobile frame, — Essieu cruciforme = cruciform axle.

(1) Cf. *Revue Générale des Chemins de fer*, January 1932, page 10, article by M. PAR-MANTIER.

(2) Cf. *Bulletin of the Railway Congress*, January 1930, Report No. 5, Question V, Madrid Congress, page 99.

Owing to a failure of the primary circuit, through defective circulation, the locomotive was withdrawn from service in 1933 (1).

2. Velox locomotive.

The O.C.E.M. have designed in collaboration with the *Electro-Mécanique Company*, the application of a Velox boiler to a 4-6-0-B locomotive on the *P.L.M. Rys.*

This type of oil-fired boiler is designed on an entirely new principle; it has not been used so far except in stationary plant or on ships.

The principles on which it works are the following (fig. 81) :

(a) Combustion under pressure.

The combustion takes place in a combustion chamber into which air is driven at 1.5 kgr./cm² (21 lb. per sq. in.) through a burner in the centre of which the fuel oil is injected. Carrying out the combustion under pressure increases the heat released per m³ of gas and the speed of combustion, which makes it possible to reduce the volume of the combustion chamber considerably.

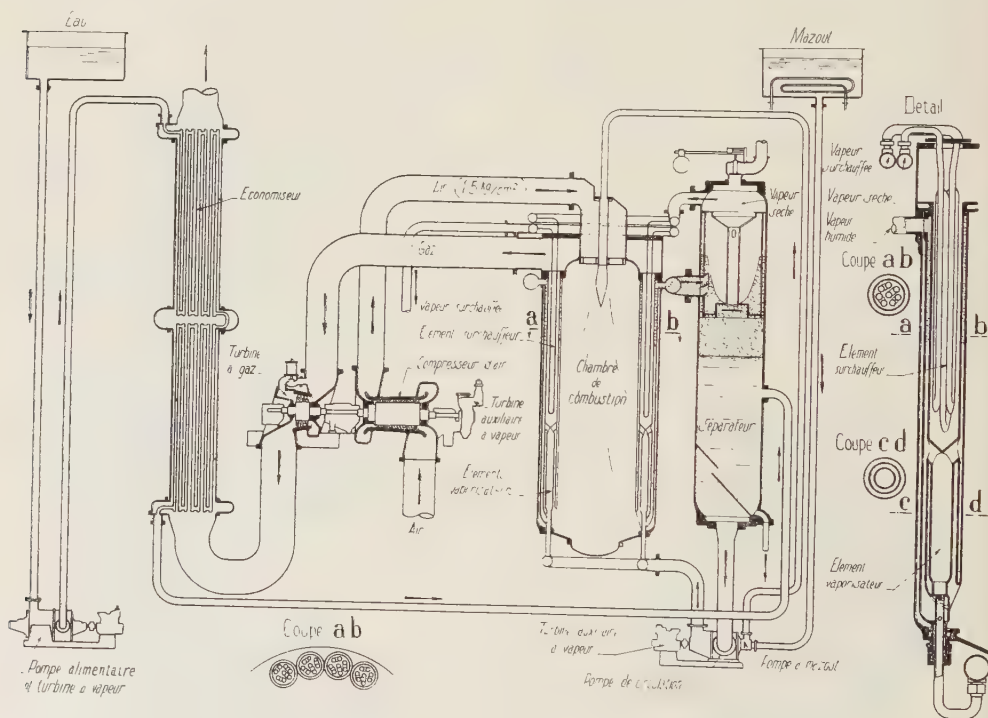


Fig. 81. — Diagram of the Velox boiler.

Explanation of French terms:

Chambre de combustion = combustion chamber. — Compresseur d'air = air compressor. — Coupe = section.
 — Eau = water. — Economiseur = economiser. — Elément surchauffeur = superheater element. — Eléments vaporisateurs = evaporating elements. — Mazout = fuel oil. — Pompe à mazout = Fuel oil pump.
 — Pompe de circulation = circulating pump. — Pompe... vapeur = supply pump and steam turbine. — Séparateur = separator. — Turbine à gaz = gas turbine. — Turbine auxiliaire à vapeur = auxiliary steam turbine. — Vapeur humide = saturated steam. — Vapeur surchauffée = superheated steam. — Vapeur sèche = dry steam.

(1) *C. Revue Générale des Chemins de fer*, August 1934, page 103, article by M. CHAN.

(b) *High-speed circulation of the combustion gases and of water to be evaporated.*

This high speed considerably activates the heat transfer by convection between the two fluids and makes it possible to obtain coefficients of heat transfer higher than those obtained by radiation in an ordinary firebox. Consequently the heating and superheating surfaces can be reduced considerably and the evaporator and superheater elements can be made of small diameter and arranged round the combustion chamber to which they act as a clothing. The size and weight of the whole boiler are considerably reduced.

(c) *Recovery of energy available in the gases, mechanical energy of the gas under pressure at very high speed and remaining thermal energy.*

The first is recovered in a gas turbine driving the centrifugal compressor which supplies compressed air for combustion.

The second is absorbed by an economiser which heats the feed water. This economiser also profits by the advantage due to the high speed of the gases for transferring heat, and consequently the size is very much reduced.

These arrangements, whilst reducing the weight and space occupied, also give a high thermal efficiency for the generator as a whole; in spite of the high speed of circulation of the gases, the loss of load is only some tenths of an atmosphere. Moreover, the gas turbine which works at a high temperature, and the centrifugal compressor are both equipment of relatively high efficiency. The losses in this apparatus are moreover recovered: the losses in the turbine as heat to preheat the feed water, and the losses in the compressor in the form of heat for preheating the combustion air.

The Velox boiler on the other hand requires a relatively large number of auxiliary fittings, besides the gas turbine,

the compressor and the economiser. These are:

(α) *Circulating pumps.* — One pump forces the feed water through the economiser in a steam separator where a circulating pump takes it at the same time as the separated water to introduce it into the evaporating elements. In addition an oil pump introduces the fuel into the burner through filters and a preheater with steam coil.

(β) *Centrifugal separator.* — The emulsion of water and steam leaving the vaporising elements is discharged at high speed on the periphery of a cylindrical reservoir forming a centrifugal separator. The separated water mixes at the bottom with the preheated feed water and the steam leaves from the top part to pass through the superheater before being used.

(γ) *The starting auxiliaries* look after the working of the compressor and the pumps, when the boiler is not under pressure.

Figure 82 shows the way the Velox boiler is mounted on the frame of the 4-6-0 locomotive of the P.L.M. Ry. The pressure of this boiler is 20 kg./cm² (284 lb. per sq. in.).

The starting motors are electrical. The current is supplied by a motor-generator set on the front of the tender, driven by a diesel engine, on gas oil fed by a small auxiliary reservoir. This gas oil is also used to light up the oil burner, the lighting up being by an electrical resistance.

In normal working the pumps are driven by a steam turbine. Another steam turbine gives the gas turbine the necessary additional power to drive the compressor and regulate it, whereby the activity of combustion and evaporative power of the boiler is increased if need be. Apart from this regulator, the whole equipment is automatic.

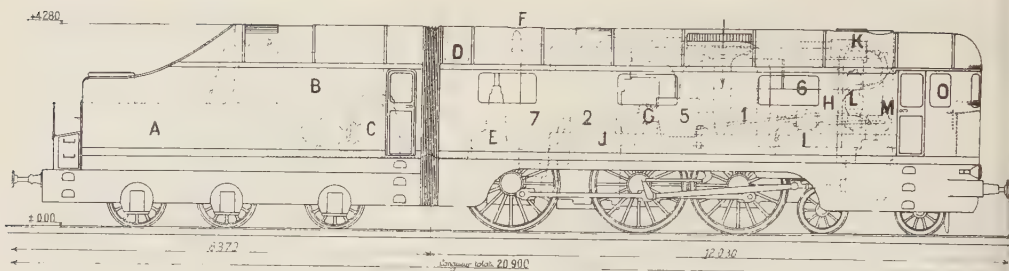


Fig. 82. — P.L.M. 230-B (4-6-0) locomotive with Velox boiler.

1. Combustion air compressor.
2. Combustion chamber.
5. Gas turbine.
6. Economiser.
7. Separator.
- A Water tank.
- B Oil reservoir.
- C Starting motor-generator set.
- D Feed water heater — condenser.
- E Pumps.

- F Safety valves.
- G Stand-by steam turbine.
- H Starting motor.
- I Main bed plate.
- J Ring carrying combustion chamber.
- K Steam regulator.
- L Air pump.
- M Reversing gear.
- O Driver's cab.

The oil reservoir is fitted on the tender in the place of the usual coal bunker.

The low calorific inertia of the boiler will enable the locomotive to be very flexible to drive, and the steam pressure should be raised very quickly.

Oil firing and the small size of the boiler has made it possible to put the cab at the front end, which makes it easier to streamline the engine.

III. — Locomotives with special types of engines.

O.C.E.M. triple-expansion locomotives.

The O.C.E.M. have designed for the French Rys. a 4-6-4 high-power triple-expansion locomotive (fig. 83).

The boiler pressure is 25 kgr./cm² (356 lb. per sq. in.) and the boiler includes an outer firebox of the *Belpaire* type, with steel inner firebox, a combustion chamber, a primary superheater, and a secondary superheater.

The plate frames are located outside the wheels. The four-wheeled leading bogie and rear truck are of a new type.

The high-pressure and medium-pressure high-speed engines drive the coupled axles through jack shafts, gears and articulated connecting rods. The inside low-pressure cylinders drive the first coupled pair of wheels in the usual manner.

The braking method is also new. The

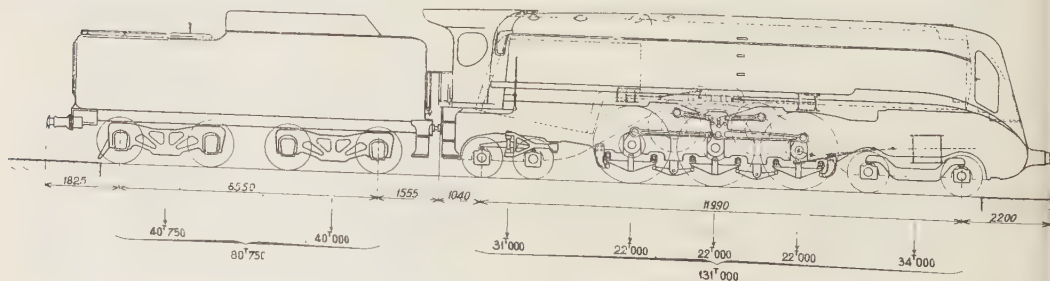


Fig. 83. — O.C.E.M. triple-expansion locomotive.

brake blocks act on a special drum cast on the body of the driving wheels.

The locomotive is streamlined.

high-pressure) or the kind of drive of the axles (individual drive).

* * *

IV. — Summary.

The French Rys. have under construction or are designing several new kinds of piston locomotives characterised by the type of engine (high-speed or combined), the kind of boiler (special or

CHAPTER II.

Turbine locomotives.

The following table gives the characteristics of the turbine locomotives in service, under construction, or being designed by the Railways consulted.

RAILWAYS.	Germany.		France.	Sweden.
	Deutsche Reichsbahn		Main-line Railways	Grängesberg- Oxelösund Ry.
Builders	Krupp.	Maffei.	Schneider.	Ljungström.
Number of locomotives	1	1	1	3
Type	4-6-2	4-6-2	4-6-4	2-8-0
Maximum speed	100 km./h.	—	140 km./h.	70 km./h.
Diameter of driving wheels.	1.650 m.	1.750 m.	1.500 m.	1.350 m.
Adhesive weight	—	60 t.	58.5 t.	72 t.
Total weight (in working order)	113.7 t.	104 t.	122 t.	117.5 t.
Boiler { type	Normal.	Normal.	Normal.	Normal.
{ pressure	15 kgr./cm ²	22 kgr./cm ²	25 kgr./cm ²	13 kgr./cm ²
Turbine { type	Action.	—	Action.	Reaction.
{ system	Zoelly-Kr u	—	Schneider-Westinghouse.	Ljungström.
Condensing or not	Condensing.	Condensing.	Not condensing.	Not condensing.
Number of { forward	1	1	3	1 with reverse
turbine { reverse	1	1	3	gear.
Number of r. p. m. of the forward turbines at the max. speed	8000	...	10500	...
Axle drive	Reduction gear and loose axle with rods.	Reduction gear and loose axle with rods.	Reduction gear and hollow shaft with Westinghouse elastic drive.	Reduction gear and loose axle with rods.
Ratio of reduction of turbine shaft to the loose axle or hollow shaft	$\frac{24.3}{1}$	...	$\frac{21.2}{1}$	...
Situation	In service.	In service.	Under construction.	In service.

There seems to be a tendency to give up *condensing*. The simplification and

saving in first cost obtained thereby seem to compensate partly for the loss

due to incomplete expansion. In addition the exhaust of the turbine to atmosphere gives back the advantages accruing from automatic regulation of the combustion by the exhaust, whereas an error in the adjustment of the draught fan of a condensing locomotive considerably reduces the overall efficiency. The blast not being intermittent as in the case of piston locomotives, for equal draught a lower back pressure will be sufficient.

I. — Ljungström locomotive of the Grängesberg-Oxelösund Ry. ⁽¹⁾.

1. Description.

The Swedish Grängesberg Oxelösund Ry. has built and put into service a non-condensing Ljungström turbine locomotive and has two other locomotives of the same type under construction.

These 2-8-0 locomotives, intended for goods working, are provided with an ordinary type of boiler with a pressure of 13 kgr./cm² (185 lb. per sq. in.) and a superheater giving steam at 400°C. (752°F.).

The turbine, carried at the front end of the engine, drives through reduction gear the loose axle which drives the 4 coupled pairs of wheels through coupling rods in the usual way. The gear box has a reversing gear.

The power of the turbine is 1 370 H.P. on the average and 2 000 H.P. peak load. The steam from the superheater passes through a steam filter before being introduced into the nozzles. The control of the nozzles from the cab makes it possible to regulate the power of the turbine, the boiler regulator being always fully open.

2. Results of tests.

Tests have shown that the steam tur-

bine of this locomotive retains a high efficiency at full load, between 70 and 80 %, over a wide speed range (25 to 65 km. = 15.5 to 40.4 miles an hour).

Comparative tests have been carried out with this locomotive and a three-cylinder simple expansion superheated locomotive, hauling a train of the same tonnage (1 600 tons) at the same average speed (30 km. = 18.6 miles an hour) over the same run (102 km. = 63.4 miles) at one day interval. These tests have given a consumption of 1 035 kgr. per 100 tonne-kilometres hauled by the turbine locomotive and 1 358 kgr. by the piston locomotive, representing a saving of 23 % in the case of the former.

Tests with a dynamometer car gave consumption figures of 1.3 kgr. of coal and 10.7 litres of water per effective horse-power/hour in the case of the turbine locomotive, and 1.7 kgr. of coal and 13.2 litres of water in the case of the piston locomotive.

3. First costs and maintenance costs.

The Ljungström locomotive, in service on the Grängesberg-Oxelösund Ry. since 4 years, has run some 175 000 km. (108 700 miles) without any failure.

At the end of 100 000 km. (62 000 miles), various parts were examined: there was no wear of the gear teeth and the turbine blades were in perfect condition.

II. — Turbine locomotives of the Deutsche Reichsbahn.

The *Reichsbahn* gives no new information on the *Krupp* and *Maffei* turbine locomotives described in Report No. 5, Question V, of the Madrid Congress.

We wish to call attention in this connection to an article published in the 15th October 1935 number of *Glaser's Annalen*, under the signature of Herr

⁽¹⁾ See *Bulletin of the Railway Congress*, August 1933, p. 749.

BURMEISTER, Chief Engineer at Essen ⁽¹⁾. Although this document has no official character, we think it may be of interest to analyse it briefly.

Running tests and tests on the test plant on the Krupp locomotive brought out a series of important losses due to the following causes:

— The regulation of the auxiliary turbines, especially the draught fan turbine not being automatic, an excessive quantity of steam is used when running light or at low speed.

— High steam consumption by the main turbine at starting or when shunting, as this turbine only has a good efficiency when the locomotive is running at speed.

— High consumption by the reverse turbine during shunting or when running in the reverse direction. Indeed, to reduce the fan losses in forward running, this turbine was only given a small number of speeds and only has a good efficiency at high speed.

The alterations now being carried out will remove these various losses by the following arrangements:

(α) It was made possible to cut out the reverse turbine when running, by means of a reduction gear and reverse gear, so that it can be used to drive the locomotive in either direction. It is therefore available for use when shunting, and the provision of the gears will ensure it running at the working speed.

(β) The 3 auxiliary turbines driving the cooling fan, the water circulation pump and the draught fan will be arranged in series, so that the total temperature drop can be divided between them, and in this way the efficiency of each improved in view of their low power. In addition they are to be fed by bleed-

ing steam from the first stage of the main turbine, which gives the automatic regulation required. For running light, the set is provided with steam through a pressure reducing valve.

It was expected that these rearrangements would save some 50 % of the steam used by the auxiliary turbines.

A scheme on the same lines was to be drawn up for the Maffei locomotive.

III. — Schneider locomotive for the French main-line Railways.

Messrs. Schneider & Company designed, in collaboration with the O.C.E.M., a non-condensing turbine locomotive with individual axle drive.

This 4-6-4 locomotive is intended for hauling main-line trains at high overall speeds, with few stops.

It will be equipped with a boiler of the classic type, the pressure being increased to 25 kgr./cm² (356 lb. per sq. in.), special steels being used.

The engine will consist of three sets of Schneider-Westinghouse turbines, running at 10 500 r.p.m. when the speed is 140 km. (87 miles) an hour, and driving the axles through double reduction gear and concentric hollow shafts, with Westinghouse elastic drive.

Each set will include a forward turbine and a reverse turbine.

The exhaust will be led directly to the smokebox.

Each motor set will form, with its axle, an independent unit controlled from the cab in parallel with the others or independently thereof.

A special device will be fitted to prevent the wheels skidding.

The locomotive will be streamlined.

IV. — Summary.

Tests of turbine locomotives are proceeding, the tendency being to give up condensing. There is one locomotive being tested with individual axle drive.

(1) See also *Bulletin of the Railway Congress*, July 1936. number, p. 707.

PART THREE.

2. *Rollers and brakes.***Testing steam locomotives.****A. — Tests at experimental stations.**

CHAPTER I.

Locomotive test plants.**I. — Situation and dates built.**

There are only two locomotive testing plants on the territory covered by the Railways consulted: the *Reichsbahn's* locomotive and railcar testing plant (1) built in 1930 at Grunewald, and the O.C.E.M. locomotive testing plant (2,3) opened in 1933, at Vitry-sur-Seine (fig. 84).

II. — Description of the test plants.**1. General arrangement.**

The two test plants have been designed on the same principles. Each consists of a certain number of braked rollers the position of which can be adjusted on a metal framework which is anchored to a very substantial block of concrete. The locomotive to be tested is supported on these rollers on which the locomotive driving wheels rest only, or on which both driving and carrying wheels rest, so that they can exert on a recording dynamometer through its rear coupling a force which is none other than that at the tread of the driving wheels.

(1) Cf. *Glaser's Annalen*, 1st March 1931, article by Messrs GÜNTHER and SOLVEEN. See also *Bulletin of the Railway Congress*, June 1932 number, p. 1171.

(2) Cf. *Revue Générale des Chemins de fer*, October 1933, page 381, article by M. PLACE.

(3) In this report the « Office Central d'Etudes de Matériel de Chemins de fer français » (Central Locomotive and Rolling Designing Office of the French Railways) is described as the O.C.E.M.

The Grunewald test plant has only three rollers, each braked by an individual brake arranged to take the locomotive driving wheels. The carrying wheels rest on sections of standard gauge track.

At the Vitry plant, on the contrary, all the wheels of the locomotive are carried on rollers. There are 8 of these rollers, and 6 of them can be braked.

At Grunewald the rollers rest on ordinary bearings, and at Vitry on roller bearings.

The brakes used are hydraulic brakes of the Froude type.

At Grunewald each of the three brakes is arranged below the corresponding roller. This required the use of a brake of small dimensions running at high speed, and consequently driven from the roller through reduction gear.

The roller and the brake coupled to form a rigid unit known as the brake set bolted to the upper table of the test plant by pressure screws. The sets are moved by means of an overhead 10-ton crane.

At Vitry the 6 brakes can be moved independently from the rollers on two beds parallel to the main bed, one on the right and the other on the left of the test plant. Three brakes move on each bed. Each of these 6 brakes can be coupled directly to the end of the shaft of any one of the 8 rollers, by means of a flexible coupling.

The bearings of the rollers are carried on the bed through rollers which make it possible to move one or several of the rollers easily, by means of an electric motor, or by hand. Each of the rollers can be moved when carrying 30 tons. Once the rollers and the brakes are coupled together, the unit as a whole can be moved. Once the brake roller is correctly placed, the rollers carrying the bearings can be taken away and the bearings bolted to the bed.

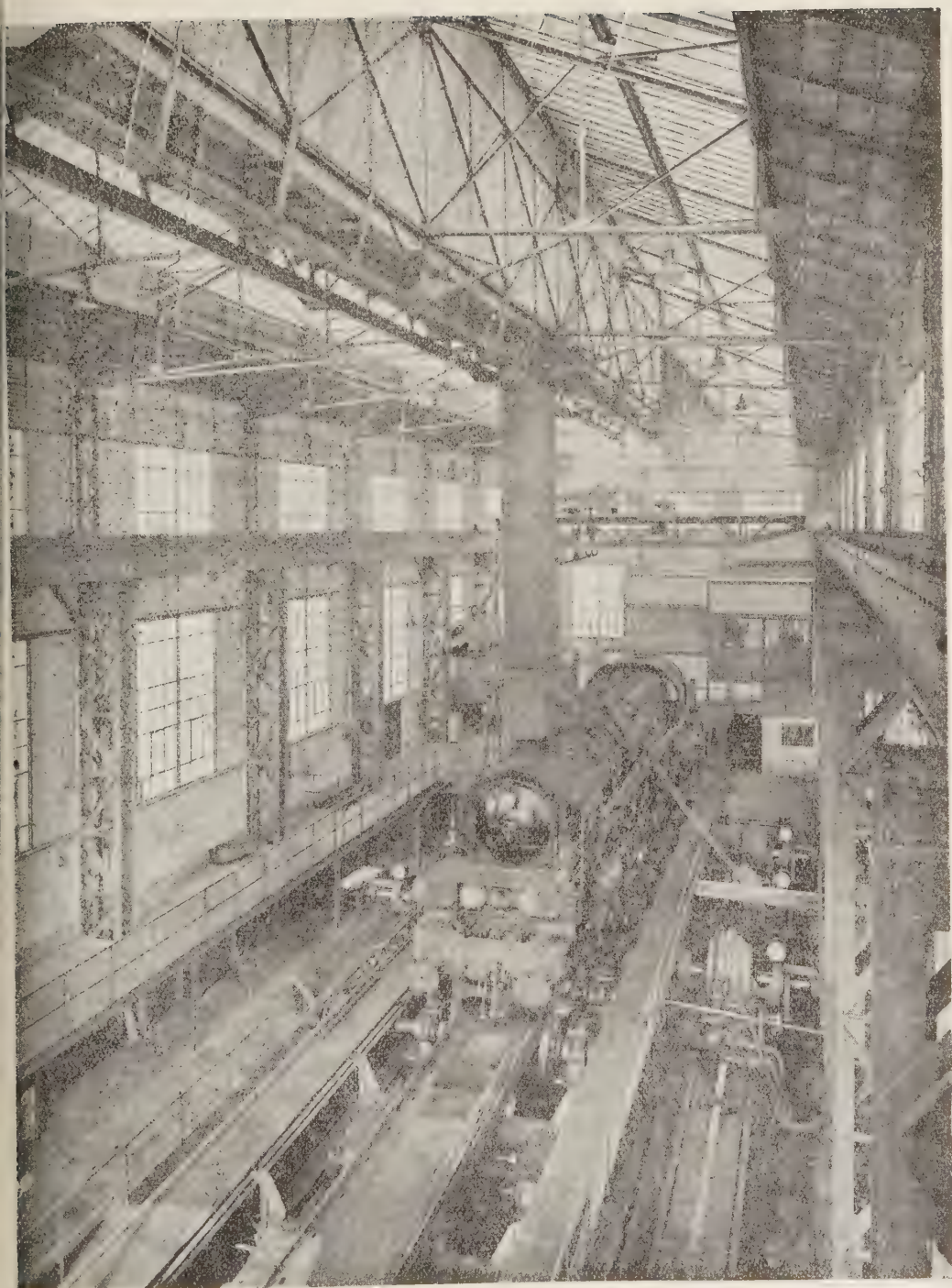


Fig. 84. — Vitry test plant. — General view.

3. Arrangements for bringing in and locating the locomotives.

At Grunewald and at Vitry, the top of the rollers and the rails taking the carrying wheels on each side is slightly below the incoming road. In between the bed there is a special platform carrying two rails which can take the flanges of the locomotive wheels, these flanges being guided on the inside by anglebars.

On the locomotive arriving at the test plant it runs onto this platform, which has been raised to the level of the incoming road. The drawbar is then coupled up, the platform lowered, and the locomotive is carried on its usual supports.

In addition at Vitry there are dashpots connecting the locomotive to the test plant by the back buffer beam of the locomotive, intended to damp out longitudinal vibrations resulting from imperfect balancing of the motion.

4. Other installations and auxiliary equipment.

(a) *Firing platform.* — At each test plant there is a firing platform which takes the place of the usual tender front, the height of which can be adjusted to suit the level of the locomotive cab.

(b) *Measurement room.* — The two test plants have measurement rooms, situated at Vitry behind the firing platform. These rooms contain the dynamometer tables. The apparatus on the tables is driven at Grunewald by the movement of one of the brake units, and at Vitry from one of the crank pins of the locomotive on the lines of a speed indicator.

(c) *Evacuating the gases and separation of the cinders.* — At Grunewald the gases escaping from the chimney of the locomotive are collected in an articulated hood and led into a centrifugal separator which collects the cinders for weighing.

(d) *Anti-skidding devices.* — Lubrication oil from the locomotive, falling on the rollers, is liable to set up skidding.

At Grunewald this is avoided by a sanding device which throws sand at the point of contact between the wheels and the drums. The sand is then collected by a dust catcher.

At Vitry a jet of water cleans the drums continuously throughout the trial.

(e) *Lifting equipment.* — Besides the 10-ton overhead crane mentioned above, the Grunewald test plant has a 1.5-ton truck for bringing in the coal.

The Vitry plant has also an overhead crane for lifting up the coal tubs.

The test plants have water tanks accurately gauged and graduated for supplying the locomotive boilers.

III. — Description of the brakes.

The articles quoted at the beginning of the present chapter describe in a detailed fashion the Froude hydraulic brakes used in the two plants.

The Grunewald brakes are dynamometrical. The stator is suspended on the axles of the carrying rollers about which it would revolve if not held by an arm acting on a liquid dynamometer.

The Vitry brakes are not dynamometrical. However, the power they absorb has been ascertained by measuring the amount of water and the degree to which it is heated. The valves allowing water into the brakes and those letting it out are regulated simultaneously from the same control point.

These brakes are fed by a pump the speed of which is proportional to that of the brake, so that the form of their characteristics is such that the regulation of the running speed is easy and stable.

The general equation of these characteristics is $P = K D^5 n \alpha$,

P being the power absorbed,
D the diameter of the rotor,

n the number of revolutions per minute,

α a coefficient depending on the quantity of water. It varies between 2.8 maximum and a figure slightly over 1 when the quantity of water is nil and the brake revolves in air.

The German brakes have much the same characteristics.

IV. — Dynamometric apparatus.

The dynamometers used at Grunewald and Vitry are of the hydraulic type.

1. Dynamometers.

The dynamometer at Grunewald is in three stages. It has 3 pistons of different diameters so that it is possible to measure up to 3 tons, 15 tons, or 35 tons. The pressure is transmitted to the gauges by pipes.

At Vitry the fluid compressed by the tractive effort acts on three small measuring pistons loaded by one tared spring. The deflection of this spring gives the tractive effort on three different scales.

2. Dynamometer table.

The dynamometer table at Grunewald has an automatic planimeter, receiving indications from the traction dynamometer and having a disc which revolves proportionally to the distance covered. This planimeter gives the work done.

At Vitry the dynamometer table records :

— The *time*, given by a direct-current electric motor at constant voltage and fitted with a ball regulator ;

— the *time*, given by a chronometer ;

— the *distance covered* ;

— the *drawbar pull* ;

— the *speed*, given by an Amsler differentiator on which the distance travelled and the time passed act ;

— the *work*, given by an Amsler integrator receiving the tractive effort and the distance travelled ;

— the *power*, given by an Amsler differentiator which is acted upon by the work and the time.

The recording paper can be made to unroll in proportion to the time or the distance.

In addition, at both plants the instantaneous values of the various data recorded can be read off directly on suitable dials.

V. — Capacity of the plants.

1. Number of braked axles.

The Grunewald plant can only brake 3 driving axles, whereas the Vitry plant can brake 6.

2. Maximum dimensions of the locomotives.

The length of the test pits at Grunewald and Vitry is 24 m. (78'9").

At Grunewald the minimum wheelbase at which the brakes can be fitted is 1.420 m. (4' 8") between two axles.

At Vitry the total wheelbase of a locomotive must not exceed 22.44 m. (73' 7 1/2") with 1.35 m. (4'5 5/32") as the minimum between two axles.

Both tests plants can be extended. At Grunewald provision is made for increasing the number of brake sets to 5. At Vitry 3 additional supports could receive rollers, which would increase the number of axles to 11 ; in addition the number of brakes can be increased.

3. Maximum axle load.

The maximum axle load is 20 tons at Grunewald and 30 tons at Vitry.

4. Maximum effort at the tread.

The maximum force at the tread that can be recorded at Grunewald is 35 tons, and 45 tons at Vitry.

5. Maximum power absorbed by the brakes.

The maximum power the brakes can absorb is limited :

- by the maximum or minimum volume (1) of water injected ;
- by the maximum torsion allowable on the brake shaft ;
- by the permissible heating up of the brake water (50°C. = 122°F.).

These conditions are translated by the following figures :

— at Grunewald, each brake can absorb up to 300 H.P. at 22 km. (13.7 miles) an hour, and 40 to 1 400 H.P. at 100 km. (62 miles) an hour ;

— at Vitry, each brake can absorb up to 1 200 H.P. at 25 km. (15.3 miles) an hour, and from 600 to 1 900 H.P. at 160 km. (100 miles) an hour.

6. Maximum speed of the brake rollers.

The maximum speed for locomotives tested at Grunewald is 100 km. (62 miles) an hour. The maximum attained was 123 km. (76.4 miles) an hour. For 2-cylinder locomotives, this speed has been limited to 80 km. (50 miles) an hour.

At Vitry the brakes are not guaranteed against bursting over 650 r.p.m. In the case of rollers with new tyres, of 1.30 m. (4'3 3/16") diameter, this angular speed represents a maximum peripheral speed of 160 km. (100 miles) an hour, a speed which falls to 150 km. (93 miles) an hour when the tyres are only 1.22 m. (4') in diameter.

VI. — Accuracy and checking of the measurements.

1. Agreement between the effort at the tread and the effort recorded.

So that the effort transmitted to the dynamometer shall be the same as the force at the tread of the tyre on the horizontal track, it is essential that the centre line of the axles should be exactly on the same vertical line as the centre

lines of the rollers. If this condition is not fulfilled the weight of the locomotive has a horizontal component which adds or detracts from the tractive effort on the dynamometer, according as the axles of the wheels are in front of or behind the rollers. Supposing all the pairs of wheels are 1 mm. out on a locomotive with 1.50 m. diameter driving wheels, weighing 100 tons and exerting a tractive effort of 7 tons, the horizontal component of the weight will be 71 kgr. or 1 % of the measurements recorded.

The agreement between the centre line of the axles and that of the rollers is made with special instruments.

2. Dynamometer plant.

(a) Accuracy required.

When putting the Vitry plant into service, the following approximations were required as regards the data reported on the dynamometer table :

— for the tractive effort ± 2 % the actual forces exerted on the dynamometer being obtained by a special taring device.

— for the speed ± 1.5 %, the actual speed being known by measuring the time taken to run a definite distance (figures supplied by the length of the paper and the chronometer) ;

— for work at the tread ± 3.5 %, the work resulting from the knowledge of the real force over a known distance ;

— for the power at the tread ± 5 %, the actual value of the power being obtained knowing the actual work during a given time.

During the reception tests the errors observed were much lower than the specified approximations.

(b) Control apparatus.

To control the accuracy and constancy in time of the indications of the dynamometer, a tare box is available, the indications of which are based on the defor-

(1) This minimum is obtained when the injection is nil, the rotor turning in the air.

nations of a hollow cylinder filled with mercury.

(c) *Constancy of the indications given during a trial.*

The piston of the dynamometer is mounted in the press pot without packings, so as to reduce friction and increase the exactitude of the indications. As the piston is not absolutely tight, at the end of some hours it might advance a few millimetres. A small electric pump, known as the compensation pump, pumps back oil into the press pot as soon as the piston moves, in order to restore it to its initial position.

VII. — Constancy of the speed.

The *Froude* brakes being self-regulating, the constancy of the speed is obtained when the driving force remains constant, and this remains so to the extent that the boiler pressure is constant. When the fire is well handled, the speed remains constant within 1 %.

VIII. — Distribution of the driving power between the different pairs of wheels.

The Grunewald brakes each being fitted with a dynamometer, it is easy to check and make sure that the forces upon each roller are equal, or if need be to make sure of a given distribution of the driving force on the different rollers.

As the Vitry brakes are not fitted with dynamometers, individual preliminary regulation of these brakes has been carried out, by having the total power of the locomotive at the same speed absorbed in turn by each of the six brake rollers.

The equality of the dimensions of the brakes and their working under identical conditions, an identity ensured amongst other things by their hydraulic inter-communication, give the certainty that the force absorbed at the speed of

regulation will be retained at the other speeds. This result has been proved to within 1 % during the tests of a diesel locomotive fitted with independent driving axles.

Individual regulation of the brakes makes it possible, in addition, to make a different distribution to the power absorbed. This power can be known, as shown above, by measuring the water output, and the increase in its temperature.

IX. — Effect of the absence of air draught on the working of the locomotive.

The O.C.E.M. estimate that this influence, acting either on the exhaust or on the losses by radiation, are negligible against the values to be measured, such as the efficiency of the boiler or that of the cylinders, and that in any case it does not affect comparative measurements.

X. — Tests carried out on the test plant.

The tests carried out at the Vitry test plant are chiefly power tests, consumption tests, efficiency tests, tests in connection either with the whole of a locomotive or of parts of it, or auxiliary equipment of a locomotive.

There are three main and quite distinct classes of tests which, according to the O.C.E.M., can be carried out at the test plant :

1. Comparative tests, either between two locomotives, or on the same locomotive before and after altering it. Almost all the tests carried out so far fall within this category.

2. Tests of a locomotive of new type, which involve checking certain working conditions as laid down in the specifications.

3. Tests of a more scientific nature, for which the test plant seems to be particularly suitable. This class can cover tests on the form and mixture of the gaseous currents in the exhaust of loco-

motives, the determination of certain coefficients of heat transfer, enquiries into the humidity in superheated steam and its influence on the efficiency, investigations into the balancing of locomotives.

To these three classes of test the O.C.E.M. think it is necessary to add a fourth, i.e. an investigation into the improvement of the mechanical resistance of the locomotive, the boiler, the mechanism, the running gear. Locomotives do much harder work on the test plant than in actual service, first of all because they are more often made to work at their maximum power, and also because they are made to work during the whole duration of the test (usually 2 hours) without stop, which means nearly 2 1/2 hours including the preparatory period. It is difficult to make such a long test at maximum power on the line, owing to operation restrictions. During these tests, various defects are revealed; when they have been remedied and do not re-occur on the test plant, the O.C.E.M. consider they will be avoided on the road.

No account of the absence of air current has been taken in interpreting the results. These results are given as got out to the railways; the O.C.E.M. considers that this method is sufficient for the object looked for.

This, however, is not the opinion of the *Reichsbahn* Testing Section, who, seeing the difficulty found in taking into account by calculation the absence of air resistance, have abandoned the idea of carrying out power tests on powerful locomotives at the Grunewald test plant. The test plant is only used for rail motor cars and for locomotives of too little power to be able to haul a dynamometer car and a brake engine on a road test.

XI. — Behaviour of the locomotives on the test plant.

The various defects which may arise during testing on the test plant, which appear to be due to the particularly hard

work done by a locomotive during a trial, are mainly heating of the axle boxes.

The O.C.E.M. has endeavoured to reduce the frequency by two methods :

(a) By giving a certain elasticity to the rollers. Up to recently, the locomotives were carried on the rollers rigidly connected to the concrete foundation, whereas out on the line owing to the elasticity of the rails between the sleepers, and the elasticity of the ballast, the running is much less hard. Consequently pads of indiarubber have been inserted between the foundation and the braking roller bearings.

(b) By paying great attention to the rolling surface of the tyres of the locomotive and of the rollers.

Care has to be taken to avoid amongst other things :

- flats on the braking rollers (a grinding machine to correct the rollers in position has been provided);
- flats on the tyres of the wheels;
- differences in diameter between the wheels on the same axle;
- differences of centering between the centre of the axles and centre of the wheels.

* * *

CHAPTER II.

Measuring apparatus other than the dynamometer.

A certain number of measuring instruments are fitted to the locomotives being tested on the test plant, usually connected to recorders in the measuring room.

I. — Measurement of temperatures.

The Grunewald test plant has 32 resistance pyrometers, indicators, and recorders.

The Vitry plant uses resistance and thermo-electric pyrometers (with rhodium platinum-platinum couple).

The first are used to measure temperatures below 600° C. (1 112° F.) (tempera-

tures of the gas in the smokebox, steam, water, and combustion air); the second, for temperatures exceeding 600° C., are chiefly used for measuring the temperature of the firebox gases.

II. — Measurement of pressures.

The pressure gauges and vacuum gauges used do not require any special description. At Vitry, the indications are transmitted electrically to the measurement room by means of potentiometers.

III. — Measurement of outputs.

Feed water meters are fitted on the locomotives tested on the plant.

IV. — Analysis of the combustion gases.

At Grunewald and at Vitry an electric analyser gives continuously the CO₂ and CO + H₂ contents of the gases. The gases are taken from the smokebox by a small pump and pumped to the analyser.

In addition, tests are made at intervals in the laboratories of samples taken in special containers, by means of the Orsat apparatus.

V. — Studies of the motions.

The Vitry test plant possesses a stroboscopy illuminated by a high-power neon tube with which photographs can be taken.

* * *

CHAPTER III.

Carrying out a complete trial at the Vitry plant.

I. — Preparation of the locomotive.

The locomotive to be tested should be in a perfect condition. As far as possible, it should recently have been lifted and worked in.

Care should be taken to check in particular :

(a) Frame and motion :

- The exact parallelism of the axles;
- The equal diameter on the tread of the different wheels (with allowance of 0.5 mm. (0.0197") between the wheels on one axle);
- Total absence of flats on the tyres;
- Absence of abnormal play between the boxes and the journals, as between the boxes and the horns;
- The valve gear should be carefully checked, and in particular the cut-off on the indicator plate;
- The tightness of the piston rings and piston valve rings, or the poppet valves.

(b) Boiler :

- Good condition of the stays;
- Valves should be carefully set and tight (the valves and cylinder release valves should be set at 1 kgr./cm² (14 lb. per sq. in.) above the normal boiler pressure);
- Absence of leaks in the firebox;
- Tightness of the smoke box;
- Proper working order of the feed equipment;
- Perfect centering of the exhaust.

The boiler in addition is gauged cold. The extreme positions of the regulator and the exhaust are measured up (making allowance for any correction for expansion) and the space divided into 10 equal parts.

Subsequently the measuring apparatus described in the previous chapter are fitted, the locomotive is put onto the plant, coupled up with the dynamometer and the necessary pipes and connections fitted.

II. — Fuel used.

Except for special tests, the fuel used is a screened mixture of :

- 40 % briquettes from Aniche or Anzin;
- 60 % screened Aniche coal.

III. — Method of carrying out a consumption test under constant working conditions.

The engine is lighted up sufficiently soon for the boiler to be under pressure and the water level at the top point at a given hour; after this an attempt is made to run at uniform speed by proper setting of the regulator and the brakes. Once this condition has been obtained, the working conditions are allowed to stabilise themselves between 15 and 20 minutes, and then the test begins.

The test lasts at least 2 hours.

The prescribed records are made every half hour.

During the test everything is done to maintain all the conditions (speed, pressure and water level) as constant as possible, the pressure having priority over the water level so as to ensure the speed being constant.

At the end of the test the water level is not restored to what it was at the beginning; as the boiler has been carefully measured up previously to the test the necessary corrections can be made.

IV. — Measurements recorded.

The data collected during the trial are the following :

- Boiler pressure;
- Pressure in the saturated steam collector;
- Pressure in the superheated steam collector;
- Pressure in the high-pressure and low-pressure steam chests;
- Pressure in the blast;
- Depression in the smoke box;
- Depression in the firebox;
- Superheat temperature in the header;
- Superheat temperature in the high-pressure and low-pressure steam chests on both sides of the engine;
- Temperature of the exhaust steam in the cylinders;
- Temperature in the firebox;

- Temperature of the exhaust gases in front of the flue tubes and smoke tubes;
- Temperature of the feed water;
- Temperature of the surrounding air;
- Temperature of the water fed by the injectors or the feed water heater;
- CO^2 and $\text{CO} + \text{H}^2$ contents of the gases.

The dynamometer table records the speed, the tractive effort, the work done and the power. The kilometres and the time are recorded on the diagram.

The water and coal consumption, the water level in the boiler, and the losses of water are recorded at the beginning of the test properly speaking, then every half hour, and at the end of the test.

V. — Calculation of the heat balance-sheet of the boiler.

The heat balance-sheet of the boiler requires a knowledge of :

- (a) the consumption of coal;
- (b) the steam produced.

I. — Consumption of coal.

This is generally ascertained by the *Est* method; for the *P. O.-Midi Rys.* locomotives the calculations are made in addition by the *P. O.-Midi* method.

(a) *Est* method.

The quantities of coal corresponding on the one hand to the total volume of fuel remaining on the grate, and on the other hand to the total volume of clinker measured after dropping the fire are calculated. If P_1 and P_2 are the corresponding weights, the quantity of coal in the grate is taken as equal to
$$\frac{P_1 - P_2}{2}$$

(b) *P. O.-Midi* method ⁽¹⁾.

With the *P. O.-Midi* method the weight

(1) Cf. *Revue Générale des Chemins de fer*, February 1935, page 159, article by M. CHAPELON.

P_1 of coal fired from the start to the end of the test is deducted from :

— the weight P_2 burnt from the beginning of lighting up to the opening of the regulator, this weight P_2 being ascertained by calculation, according to the heating up of the water and the estimated efficiency of the boiler;

— the weight P_3 of unburnt coal equal from the calorific point of view to the weight of fuel remaining on the grate at the end of the test, this weight P_3 being obtained, after quick dumping and quenching of the fire, by analysis and determination of the calorific value of the residue.

2. Steam produced.

In order to make the results obtained with different pressures and superheat temperatures comparable, the *O.E.C.M.* calculate the *fictive* evaporation of the boilers (cf. Chapter XI in Part One).

(α) Locomotives without feed water heaters.

The evaporation is calculated starting from the weight of water measured in the feed tanks.

(β) Locomotives fitted with a feed water heater.

The weight of warm water measured by the meters on the supply side of the feed devices is corrected by the quantity of heat supplied to the water by these devices.

* * *

B. — Tests on the road with brake locomotives.

CHAPTER I.

Dynamometer cars.

I. — Types of dynamometer-car.

The dynamometer-cars used by the Railways for their running tests can be

classified in two groups according to the type of dynamometer.

1. *Spring dynamometers.* — The cars fitted with these are usually rather old, but most of them have been more or less transformed and provided with modern measuring apparatus. This group includes the cars belonging to the *Austrian Federal Rys.*, the *Belgian Rys.*, the *French Est, P.L.M.* and *P.O.-Midi Rys.*

2. *Hydraulic dynamometers.* — These are generally provided on recent vehicles and can be divided into two types :

— the *Schäffer* and *Budenberg* type, fitted with a membrane dynamometer, used by the *Reichsbahn* and *Netherlands Rys.*;

— the *Amsler* type with a piston dynamometer. This type of car is used by the *O.C.E.M.*, the *Polish State Rys.*, and the *Swiss Federal Rys.* The whole of the dynamometer equipment of these cars was built by Messrs. *Amsler*.

II. — Description of dynamometer cars.

1. French Est car.

The *Est* equipped a bogie brake van, having a gangway to give access to the test locomotive, the special tender of which has been altered to make this possible.

The drive is by a nickel-chrome steel roller applied to the tyre of one of the axles by a compressed air servo-motor, which arrangement makes it possible to get constant movement, whatever may be the condition of the tyres as regards wear.

A particular feature of the car is an electric power integrator of a special type. Figure 85 is a diagram showing how it works. A storage battery supplies current at constant voltage. C_1 , C_2 and C_3 , are the O.K. volt-hour-metre counters, R_1 and R_2 the resistances mounted as potentiometers.

The cursors b_1 and b_2 are connected to the dynamometer and the speed indicator in such a way that if V_1 is the dif-

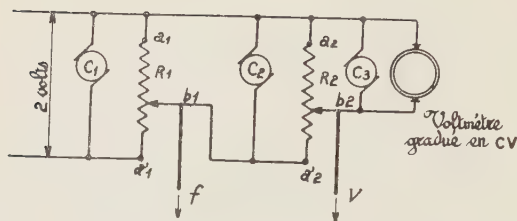


Fig. 85. — Diagram of the electric integrator of the *French Est Rys.* dynamometer car.

Note: Voltmètre... = voltmeter graduated in H. P.

ference of potential between the terminals of the accumulators, V_2 that between a_1 and b_1 , and V_3 that between a_2 and b_2 , $\frac{V_2}{V_1}$ be proportional to the tractive power and $\frac{V_3}{V_2}$ to the speed of the test train. V_1 being constant, V_3 will be proportional to the instantaneous power. This power is given in H. P. by the suitably graduated voltmeter.

At the end of a test run, if C_1 , C_2 and C_3 are the figures totalised by the counters C_1 , C_2 and C_3 , the ratios $\frac{C_2}{C_1}$, $\frac{C_3}{C_2}$,

$\frac{C_3}{C_1}$ are respectively proportional to the average values of the tractive effort, of the speed, and of the power during the test.

The accuracy of the dynamometer is checked 4 times a year by means of a special balance for taring the springs, without taking them down, the car being coupled by its drawbar hook to that of the weigh table. The flexibility of the dynamometer springs has not varied since they were put into service.

2. P. L. M. cars.

The *P.L.M.* has two six-wheeled dynamometer cars built in 1889, a description of which was given in the *Revue Générale des Chemins de fer*, February 1894 (page 97).

In 1928 these cars were altered considerably, and equipped with modern recorders. These instruments, together with the methods and devices for checking them, were described in the January 1932 number of the *Revue Générale des Chemins de fer* (page 24).

3. Reichsbahn cars.

(a) Dynamometers.

The dynamometer of the Schäffer and Budenberg type consists essentially of a tank filled with glycerine closed at one end by a brass diaphragm on which the tractive effort is applied, and at the other end by 2 Bourdon tubes, one being used for indicating, and the other for recording purposes.

(b) Apparatus on the measuring table.

The measuring table is only passed over by two paper bands driven by the axles, on each of which the tractive effort and the speed are recorded.

This last measurement is supplied by two Deuta tachometers of the eddy-current type, one the indicator and the other the recorder.

The work done at the drawbar is given by an Ott planimeter; the operators read off the work done on the totaliser of the planimeter.

(c) Checking the dynamometer and accuracy of measurements.

The checking of the indications of the dynamometer is carried out every three months by means of a precision test box checked by the State Technical Physics Office. The errors are less than 1 %.

4. O. C. E. M. cars. (1)

(a) Dynamometer.

The Amsler dynamometer of the *O.C.E.M.* cars, of the piston hydraulic type, is identical in construction with those of

(1) Cf. *Revue Générale des Chemins de fer*, April 1933, page 322, article by M. PLACE.

the Vitry test plant, and like it can give the tractive effort to three different scales.

(b) *Dynamometer table* (fig. 86).

The drive is taken by gears keyed on

one of the unbraked axles of a bogie. By inserting a variable reduction gear, tyre wear can be taken into account.

The design of the table is in all respects the same as that of the Vitry test plant.

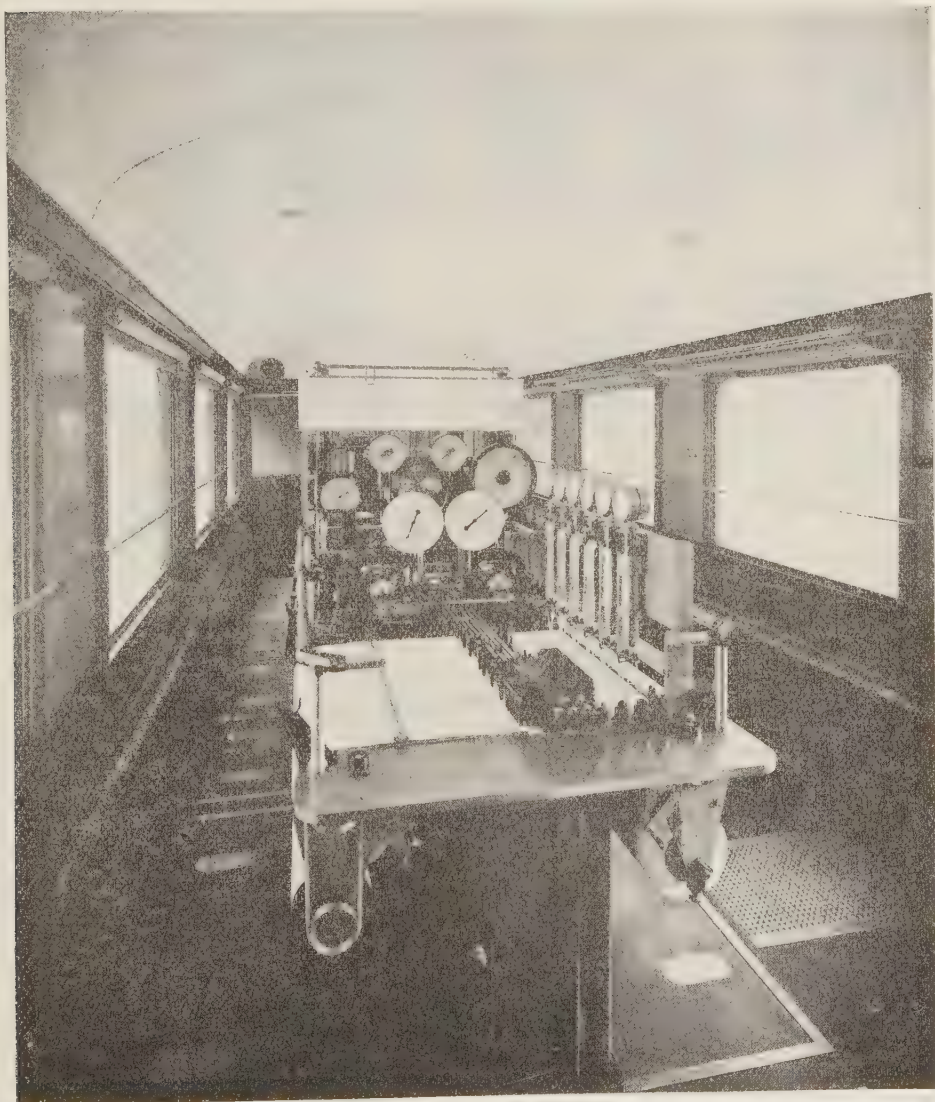


Fig. 86. — Dynamometer table of *O.C.E.M.* dynamometer car.

In addition to the equipment on the Vitry table, it is fitted with an inertia pendulum giving the sum of the effects of acceleration and gradients. An *Amsler* integrator gives the work done by these forces.

(c) *Accuracy of the measurements and checking.*

The tolerances for the car equipment are the same as on the Vitry table. In addition a maximum error of $\pm 3.5\%$ has been specified for the instrument giving the work of the inertia forces. The checks carried out before acceptance showed that the tolerances were respected.

A pump similar to that on the Vitry plant is used to make up losses resulting from lack of tightness of the dynamometer piston.

In order to make it possible to carry out periodical checks of the accuracy of the dynamometer, the drawbar has been arranged to take an adjustment box.

* * *

CHAPTER II.

Measuring instruments other than those of the dynamometer cars.

I. — Indicators.

Maihak power indicators are used quite generally to measure the indicated H. P., by all Railways carrying out tests on the line. They are also used by Railways who do not possess dynamometer cars, in particular the *Algerian Rys.* and the *Royal Hungarian State Rys.*

As a rule there is one indicator for each cylinder. Sometimes, however, in order to reduce to a minimum the length of the pipes, the *P.L.M.* fits an indicator on each cylinder end.

The *Maihak* indicators are very easy to control from a distance, i. e. from the driver's cab. The pens are applied to the

drums of the indicators, and the paper is unwound, electrically.

The indicator cocks may be operated by means of cables, as on the *Est*, or by compressed-air servo-motors, as on the *Alsace-Lorraine Rys.* (fig. 87) and the *P.L.M. Rys.*

In addition, on the *P.L.M. Rys.*, an additional servo-motor (1) makes it possible to clutch in or out the drive, by the movement of the pistons, of the drums of the indicators. In this arrangement the servo-motors drive the various apparatus by perforated steel ribbons and pulleys, the rims of which are fitted with points.

In order to ensure constancy in the records of the indicators, the springs are retared periodically.

II. — Miscellaneous apparatus.

Test locomotives are generally fitted with gauges (to measure the steam pressures, exhaust back pressure, depression in the smoke box), pyrometers and feed water meters. The indications of the instruments can be read by the operator in the cab and are repeated and recorded in the dynamometer car.

* * *

CHAPTER III.

Brake locomotives.

The method of testing engines at constant speed, now used by most Railways for their line tests, involves the hauling by the test locomotive of one or more brake locomotives behind the dynamometer car, in order to produce a retarding force and regulate the speed by varying this force suitably.

I. — Type of locomotive used.

The locomotives used for high-speed tests are generally of the 4-6-0 type.

(1) Cf. *Revue Générale des Chemins de fer* 1937, article by M. GAUBERT (being prepared)

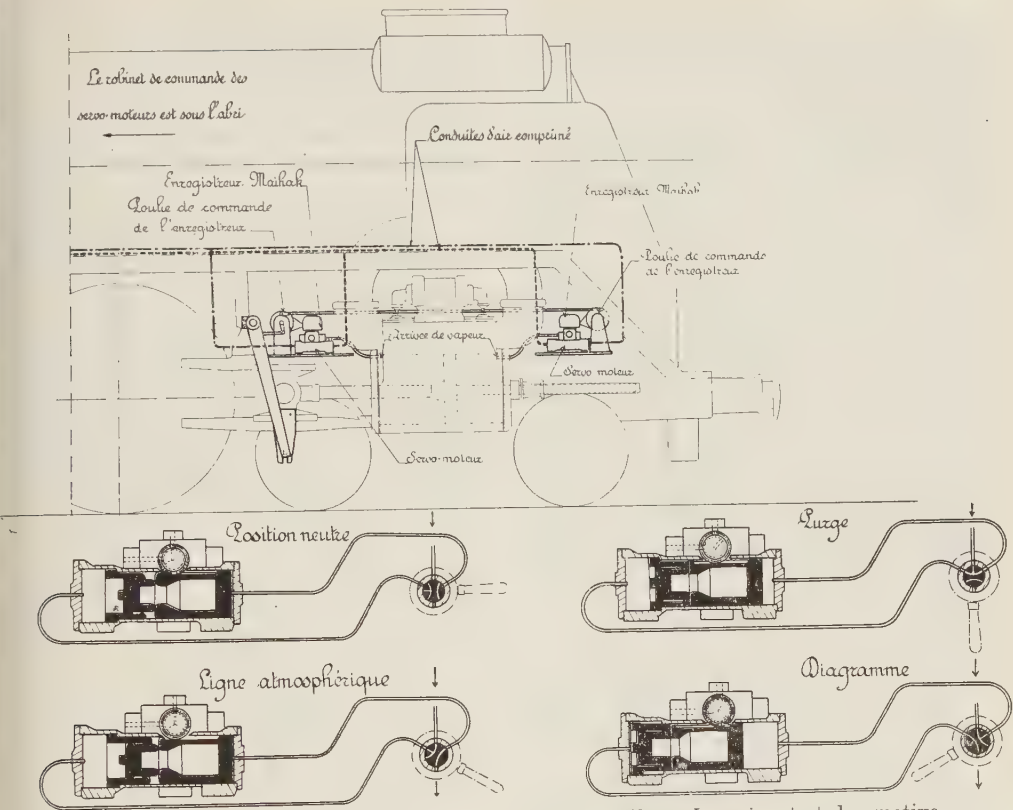


Fig. 87. — Distant control of Maihak indicator on Alsace-Lorraine test locomotive.

Explanation of French terms:

Arrivée de vapeur = steam supply pipe. — Conduites d'air comprimé = compressed air pipes. — Diagramme = diagram. — Enregistreur Maihak = Maihak recording indicator. — Le robinet... l'abri = the control valve of the servo-motors is under the cab. — Ligne atmosphérique = atmospheric line. — Poulie de commande... = driving pulley. — Purge = relief valve.

Sometimes for tests at high speed, 4-wheeled coupled locomotives are used, and for tests at low speed locomotives with 4 and even 5 pairs of coupled wheels.

II. — Working of brake locomotives.

The brake locomotive works either as a back pressure locomotive or as an air compressor (Riggenbach brake).

1. Back pressure.

Back-pressure working is used by the

Austrian Federal Rys., the French State, Nord and P.O.-Midi Rys.

Back-pressure working as a rule involves no alteration to the locomotive.

2. Air compressor.

(a) Working.

Working as an air compressor is preferred by the *Reichsbahn*, the *Alsace-Lorraine, Est, P.L.M., Netherlands*, and *Polish State Rys.*

With this arrangement the locomotive regulator is closed, and the cylinders

draw in atmospheric air, and compress it in the closed space formed by the steam pipes. Special arrangements have to be made to limit the pressure therein. As a rule a supplementary pipe is connected to the compression chamber and carries at its end a valve through which the air release to the atmosphere can be regulated.

The working as an air compressor does not require the use of a locomotive in steam. The *Netherlands Rys*, use a locomotive with the boiler not in working order, the air being compressed in a reservoir provided with a regulating valve controlled by the driver.

It is convenient, however, to use a locomotive in steam. The brake locomotive can then push the train, at speed, and it is possible to open the regulator of the test locomotive only when the fixed speed is reached, the test properly

speaking only commencing at this moment and being carried out at constant speed.

The pressure of the steam on the regulator obviates the regulator lifting and air being compressed back into the boiler. To make absolutely sure that this does not happen a safety valve is frequently fitted on the compression chamber to allow the air to escape to atmosphere as soon as its pressure exceeds boiler pressure.

Finally the presence of a locomotive in steam makes it possible to work the brakes, heat and light the test train without drawing from the locomotive boiler under test a certain quantity of steam that would have to be taken into account in the calculations.

Most of the railways use brake locomotives under steam.

Figure 88 represents the arrangement

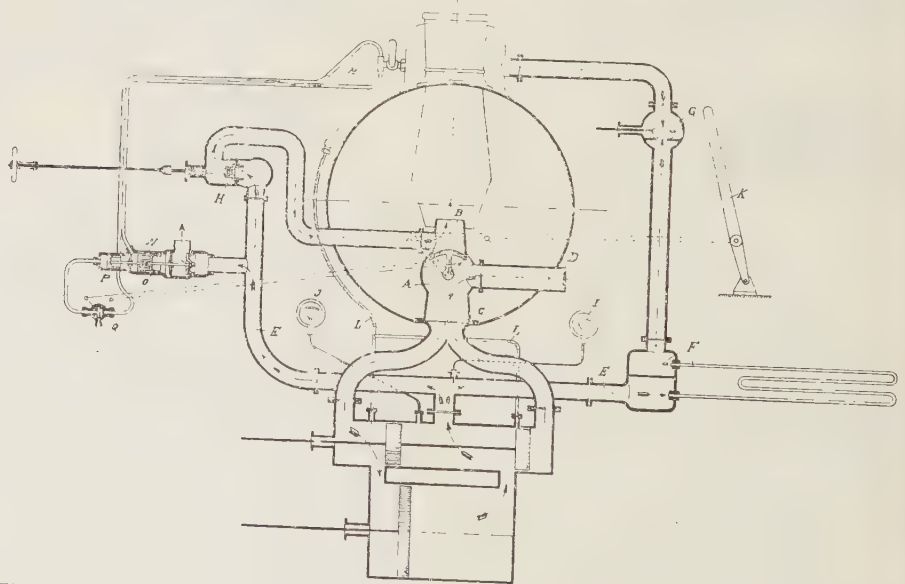


Fig. 88. — *Alsace-Lorraine Rys*. locomotive as equipped for use as a brake locomotive.

- | | |
|--|--|
| A Three-way cock in the blast pipe. | J Usual pressure gauge on the steam chests. |
| B Blast pipe top. | K Lever operating valve F. |
| C Breeches pipe. | L Water injection pipe. |
| D Air admission pipe with strainer. | M Pressure gauge pipe of balanced safety valve. |
| E Steam admission pipe to cylinders. | N Balanced safety valve. |
| F Superheater. | O Balancing piston of the balanced safety valve. |
| G Steam regulator. | P Locking piston of the balanced safety valve. |
| H Valve regulating the back pressure of the air. | Q 3-way cock actuated by the cock A. |
| I Usual pyrometer fitted in the admission pipe. | |

of a brake locomotive of the Alsace-Lorraine Rys. working as an air compressor. A cock fitted on the exhaust column can either admit fresh air by a pipe fitted with a strainer, the exhaust pipe being shut, or allow the locomotive to work in the normal way when the pipe and strainer are closed.

(b) *Maximum temperature of the compressed air.*

An endeavour is made to limit the temperature of the compressed air to 300-350° C (572 to 662° F.) This is done by injecting water and steam normally available on the engine. This injection takes place in the exhaust and moistens the air drawn in. In most case its action is completed by an injection into the low-pressure steam chests or the intermediate receiver.

III. — Resistance obtained with brake locomotives.

Few railways have ascertained accurately the resistance of the brake locomotive.

When running as a back-pressure engine, the *P. O.-Midi Rys.* obtained, with their 4-6-0 locomotives, a maximum resistance of 3 to 4 tons for speeds varying from 110 to 50 km. (68.3 to 25 miles) an hour.

The *Reichsbahn* estimates that the maximum resistance when working as a back-pressure engine can reach 1/10 of the adhesive weight of the locomotive.

IV. — Regulation of the resistance and the speed.

The resistance is generally obtained by using one, two or even three brake locomotives. The arrangement usually adopted is two locomotives; one running at fixed cut-off is used to exert a constant resistance, while the other varies its resistance to maintain the speed as constant as possible.

The driver of this latter engine is able to assure this regulation by altering :

(a) the cut-off, which makes it possible to change the area of the resistance diagram;

(b) the regulating valve which makes it possible to reduce the pressure in the compression chamber.

This arrangement is sometimes inadequate, and the driver then has to use the air brake. To make this brake more efficacious and more easy to handle, a number of carriages are attached to the test train. The *Swiss Federal Rys.* frequently use this method. The *Est Rys.*, the test section of which is over hilly country, includes in its trial train four carriages equipped with a moderate brake controlled by the driver of the regulating locomotive.

Most of the railways have succeeded in keeping the speed constant to within ± 2 km. (1.2 miles) an hour.

V. — Maximum speeds and powers.

— 140 km. (87 miles) an hour has been reached with brake locomotives during constant speed trials of the streamlined *P.L.M.* locomotives;

— 3 000 drawbar H. P. at 75 km. (46.6 miles) an hour has been recorded during tests of the 151-A (2-10-2) locomotives of the *P.L.M.*, and at 110 km. (68.3 miles) an hour during trials of the 2-4-0. 700 (4-8-0) locomotives of the *P.O.-Midi Rys.*

VI. — Maintenance of brake locomotives.

The brake locomotives have to be kept in especially good order. The high temperatures in the steam chests make it necessary to give plenty of oil, and most of the railways fit their brake locomotives with mechanical lubricators.

Brake locomotives, when properly maintained, give good service, without failure. Some Railways report that the distance run between lifting dates is less with these locomotives.

* * *

CHAPTER IV.

Carrying out a complete test.**I. — Preparation of the locomotives.**

The locomotives are taken in good state with the valve gear properly regulated, and fitted with the measuring devices enumerated in Chapter II. They are coupled to a tender fitted with gauges so as to be able to measure the water used. The tender is loaded with coal, usually in sealed sacks containing 50 kgr. (1 cwt.) and briquettes of a known weight. The qualities of coal used by the Railways were given in Chapter XI of the first part.

II. — Carrying out a consumption test under constant working conditions.

The locomotives under pressure are coupled to the test train, which is then started by the brake locomotive or locomotives, the test locomotive keeping its regulator closed. When the speed fixed for the test is reached, the regulator of the test locomotive is fully opened and the test at constant working conditions commences. The regulator is closed at the end of the test run.

1. Test run.

The test sections available on the Railways are usually about 100 km. (62 miles) long, which means a test of about one hour at high speed, and as much as two hours at lower speeds.

2. Method of firing.

This depends on the methods used for calculating the fuel consumption.

In those methods in which the heat supplied to the boiler for lighting up and building up the fire is calculated, it is essential to light up the fire specially for the test. If estimating the reserve of coal on the grate before preparation is considered sufficient, it is possible to start with a locomotive in steam.

The preparatory work is as a rule car-

ried out according to precise instructions, the quantity of coal used for this purpose being always the same, which makes it possible to obtain comparable results.

Firing during the test is done as regularly as possible. According to the methods used, the fire is allowed to die down at the end of the trial or, on the contrary, the grate is left, as far as possible, as well covered as at the start.

3. Pressure and water level in the boilers.

On many Railways an attempt is made to have the same pressure and level of water when coming in as when starting. Usually the water is brought back to its original level after stopping.

III. — Measurements recorded.

The instructions given by the Railways lay down that the water level in the boiler is to be noted; the pressure, the level of water in the tender, and the counters of the feed water heater have to be read.

When reading the water level in the boiler some Railways use level correctors when the engine is not standing on the level.

During running when recording each series of indications, the boiler pressure and the pressure in the high and low-pressure steam chests, the back pressure, the vacuum in the smoke box, and if need be the readings of the other apparatus are noted at the same time. As a rule an electric contactor is used to mark on the paper of the dynamometer car table the data recorded.

At stops the data collected at the beginning are again recorded, and the coal used en route noted.

IV. — Method of calculating the heat balance-sheet and the consumption of the engines.**1. Calculation of the coal consumption.**

The methods of calculating the heat

balance-sheet differ according to the method of evaluating the fuel consumption.

(a) *Method of the Reichsbahn.*

The Reichsbahn endeavours to have at the beginning and end of a test the same water level in the boiler and the same depth of coal on the grate. At the end of the test, at the same time as the additional water is added to the boiler, the amount of coal required to get the same depth of fire in the box as noted on the stays is added to the fire.

The *Alsace-Lorraine Rys.* follow the same practice.

(b) *Method of the Polish State Rys.*

The method used on the Polish State Rys. was perfected by Professor A. CZECZOTT, and has been described at length in the *Bulletin of the International Railway Congress Association* ⁽¹⁾.

Steam is raised in the locomotive to be tested, while running, the test train being pushed by the regulating locomotive. Care is taken that at the moment when the regulator is opened to begin the trial, the boiler is at working pressure and the water level at the normal height, with only a very thin layer of coal on the grate, only just enough to cover it.

At this moment a large quantity of coal is put on the grate so that on opening the regulator a very bright fire is obtained and the boiler pressure is kept up.

$$Co = 0.8 (0.95 A + P) \frac{C2^1}{C1} + \left(B1 + B2 \frac{C2}{C1} \right) - 0.8 D$$

wherein :

Co, is the quantity of coal burnt to evaporate the water during the test (related to coal of calorific value C1);

A, the quantity of coal in reserve before getting ready for the trial;

P, the coal used for getting ready for the trial (only briquettes);

Towards the end of the test the fire is allowed to burn out so that at the end there is once again only very little coal on the grate.

By doing this the quantity of coal at the beginning and end of the test is practically the same, and very small, which reduces the error. The whole of the coal fired during the test has consequently been used to evaporate the water.

The moment selected for closing the regulator is that at which after ceasing to fire, the pressure begins to drop. If necessary, the train is stopped on the open line in order to make the necessary records, rather than shut the regulator too late.

(c) *Method used on the Est Rys.*

The method used on the *Est Rys*, has been described in Chapter III, section I, of Part Three (Tests at the Vitry testing plant).

(d) *P.L.M. method.*

The *P.L.M. Rys.* take care to have on the grate, before getting ready for the trial, only the smallest possible quantity of coal the amount of which is estimated. The fire is so handled towards the end of the test that when stopping there is only about the same quantity of fuel as at the beginning. The quantity of coal used during the test properly speaking is then calculated by the formula :

B1, the weight of coal and B2 the weight of briquettes fired during the run;

D, the quantity of coal remaining on the grate at the end of the trial;

C1, the higher calorific value of the coal;

C2, the higher calorific value of the briquettes.

The above formula is only usable provided the preparatory work is carried out according to a given rhythm.

⁽¹⁾ Cf. July 1931 number, p. 575, article by Professor A. CZECZOTT.

The coefficients were checked during experiments carried out by the following method : two constant speed trials are carried out one on the run l , and the other on the run L .

[For example $l = 100$ km. (62 miles) and $L = 150$ km. (93 miles)].

If during the two trials the preparatory work is done in the same way and if the quantities of coal on arrival are the same, the difference in the quantities of coal burnt during the run represents exactly the amount of coal required to do an amount of work equal to the difference of the work recorded during the two trials.

(e) *P. O.-Midi method.*

The *P. O.-Midi* method has been described in Chapter III of section A of Part Three (Tests on the Vitry test plant).

The French *Nord* and the *State Rys.* use a method very similar to that of the *P. O.-Midi Rys.* In order to determine the efficiency of the boiler during lighting up, a figure on which the calculation is based, these Railways carry out preliminary lighting up and preparation tests. When the boiler is up to pressure, the fire is dropped, the fuel is weighed, and the calorific values ascertained. The *Nord* carries out preliminary tests with feed water at different temperatures.

2. Calculation of the water consumption and the evaporation of the boiler.

This is usually done according to the method described in dealing with tests on the test plant.

* * *

C. — Comparison between tests on the test plant and on the road.

So far no Railway has carried out accurate and complete comparisons of trials of a particular locomotive on the test plant and on the line.

Opinions on the subject of this comparison are only appreciations. They can as a rule be summed up as follows :

1. The test plant is particularly suitable for carrying out tests of a given equipment. The great accuracy of the instruments, etc., at the test plant and the constant test conditions reveal differences difficult to bring out in running trials.

2. Tests can be carried out on the testing plant that cannot be carried out on the line (investigations by means of a stroborama of the way in which the valve gear works, the balancing of the engine, etc.).

3. From the dynamometric point of view, the test plant gives the power at the tread, a figure little usable in practice.

In order to ascertain the load the locomotives can haul, and to draw up the timetables, it is necessary to know the powers at the tender drawbar, and the corresponding consumptions. Tests on the line alone make it possible to obtain these values with accuracy.

* * *

D. — Summary.

1. Test methods have been perfected by which it is possible to study the steam locomotive scientifically.

2. Tests can be carried out on the test plant or on the line. In both cases recent dynamometers are of the hydraulic type.

3. The test plant is particularly suitable for comparative tests of a given equipment. In addition certain tests which cannot be carried out on the line can be made on the test plant.

4. Only by tests on the line is it possible to ascertain accurately the factors (drawbar pull and consumptions) required when calculating the loads the locomotives can work.

5. Trials at constant speed with a dynamometer car and a brake locomotive form the method to be recommended when carrying out running tests.

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PART FOUR.

General summary.

A. — Steam locomotives of the usual type.

I. Increased boiler pressure.

1. Increasing the pressure improves the efficiency of the engine provided the boiler (including the superheater) and the motion are suitably dimensioned

2. A boiler pressure of 20 kgr./cm² (284 lb. per sq. inch) appears to be the maximum that can be currently used at the present time.

II. Improved water circulation.

Arch tubes and Nicholson siphons improve the circulation of water in the boilers and thereby give various advantages (less time taken to raise steam, less scale formation, increased rate of evaporation). The equipment still requires improvements to avoid the damages reported.

III. Improvement in combustion.

1. Grates are always of the classic types : either fixed or shaking.

2. Combustion chambers are relatively little used.

3. Some Railways are extending the use of smoke consuming devices and soot blowers.

IV. Raising the superheat temperature.

1. The superheat temperature corresponding to the maximum efficiency of the engine is about 400° C. (752° F.) on locomotives with a boiler pressure of

16 kgr./cm² (228 lb. per sq. in.). It should exceed 400° C. on locomotives with higher boiler pressures, not fitted with intermediate steam preheaters, but the temperature is soon limited by difficulties in lubricating the motion, and by failure of the metals to stand high temperatures.

2. Flue tube superheaters with divided headers are used almost generally. Special elements are often used to obtain high superheat temperatures.

3. Mechanical lubricators and piston rod and piston valve spindle packings with a number of rings are now usual practice on modern locomotives.

V. Feed water heating.

1. All modern locomotives are now equipped with feed water heaters, or when simplicity is particularly desired, with exhaust steam injectors.

2. Most Railways prefer the closed type of feed water heater.

3. Pumps mechanically driven off the motion of the engine are liked owing to their simplicity, so long as the running speed is not too high for their proper working.

4. Steam-driven pumps are more costly, but are more easily fitted. They are the most widely used.

5. Economisers mounted in series with exhaust steam feed water heaters are capable of giving valuable results.

VI. Air preheating.

The only test carried out by one Railway did not give any useful results.

VII. Improved blast pipe designs.

1. The use of improved blast pipes increases appreciably the power and efficiency of locomotives.

2. Opinions of the Railways are still divided as to the value of variable blast pipes.

VIII. *Improved valve gears.*

1. The use of double-ported piston valves can improve the distribution of steam to the cylinders.

2. Poppet valve gears are beyond the experimental stage and can be fitted as standard practice to locomotives.

3. Poppet valves or piston valves driven by oscillating or rotary cams have given very good results during tests. It is not possible, however, to estimate the part thereof due to the valves themselves and that due to the other improvements to the locomotives.

4. Poppet valves or piston valves driven by rotary cams, owing to the small inertia of their moving parts, appear to be particularly suited for extra-high-speed locomotives.

IX. *Improved steam circuits.*

The Railways all agree in recognising the value of improving the steam circuits of locomotives to the maximum possible extent.

X. *Compounding.*

The opinions of railways are still very divided as regards compounding.

XI. *Power and efficiency of modern locomotives.*

As a result of recent improvements in the locomotives, the specific power and the efficiency of steam locomotives have been markedly increased. Under certain operating conditions the figure of 14 % for the indicated efficiency and 9 % for the effective efficiency are being obtained.

XII. *Use and maintenance of modern locomotives.*

1. The distance run without changing engines frequently exceeds 300 km. (186 miles), and even reaches 500 km. (310 miles). The maximum distances

between stops exceed 350 km. (217 miles). Finally the average speeds are often over 100 km. (62 miles) an hour.

2. High-efficiency locomotives have been in service too short a time for the costs of a complete maintenance cycle to be available. It is therefore not possible to evaluate the effects of improvements made to these locomotives, on the maintenance costs.

XIII. *Streamlining.*

Streamlining of locomotives and trains appreciably reduces the air resistance at high speeds; it makes it possible to retain engines of old types which, if not streamlined, would not be powerful enough to reach and maintain the high speeds required.

XIV. *Miscellaneous.*

1. The use of special steels has only been extended slightly.

2. Light metals are practically not used.

3. Some railways are testing coal pushers and mechanical stokers.

4. Tests of oil firing and pulverised coal firing are very limited.

B. — *Steam locomotives of new types.*

I. *Piston locomotives of new types.*

The French Rys. have under construction or are designing several new kinds of piston locomotives characterized by the type of engine (high-speed or combined), the type of boiler (special or high-pressure) or the type of drive of the axles (individual drive).

II. *Turbine locomotives.*

Tests of turbine locomotives are proceeding, the tendency being to give up condensing. There is one locomotive being tested, with individual axle drive.

C. — Testing steam locomotives.

1. Test methods have been perfected by which it is possible to study the steam locomotive scientifically.

2. Tests can be carried out on the test plant or on the line. In both cases, recent dynamometers are of the hydraulic type.

3. The test plant is particularly suitable for comparative tests of given equipment. In addition certain tests which

cannot be carried out on the line can be made on the test plant.

4. Only by tests on the line is it possible to ascertain accurately the factors (drawbar pull and consumptions) required when calculating the loads the engines can work.

5. Trials at constant speed with a dynamometer car and a brake locomotive form the best method to be recommended when carrying out running tests.



INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

13th SESSION (PARIS, 1937).

QUESTION V.

Recent improvements in steam locomotives

of the usual type and tests of new designs (high-pressure reciprocating locomotives and turbine locomotives) as regards construction, quality of materials used, efficiency, working conditions, maintenance and financial results.

Testing locomotives

at locomotive experimental stations, and in service with dynamometer cars and brake locomotives.

REPORT

(Italy, Spain, Portugal and Colonies, Czechoslovakia, Jugošlavia, Bulgaria, Rumania, Greece, Turkey, Egypt),

by A. MASCINI,

Inspecteur en chef supérieur, Service du matériel et de la traction, Italian State Railways.

Foreword.

Our questionnaire in connection with Question V was sent to all the Railways in Egypt, Spain, Italy, Portugal and Colonies, Rumania, Czechoslovakia, Turkey, Jugoslavia, Bulgaria and Greece, belonging to the International Railway Congress Association, a total of 43.

The following 12 Administrations have answered it :

Jugoslav State Railways.
Czechoslovak State Railways.
Northern of Spain Railways.
Madrid-Saragossa-Alicante Rys.
Portuguese Railways Company.

Egyptian State Railways.
Rumanian State Railways.
Bulgarian State Railways.
Hellenic State Railways.
Mozambique Colonial Railways.
Piedmontese Tramways Company.
National Western of Spain Rys. Co.

The only one of these Administrations to report locomotives of a new type or with fundamental improvements to the classical type was the *Madrid-Saragossa-Alicante* Railways which are building 10 engines with boilers working at a pressure of 20 kgr./cm² (284 lb. per sq. m.).

No outstanding feature is to be recorded as regards Italy since 1930 ; conse-

quently when following the general lines laid down for the reports we have not dealt with the subjects in detail.

None of the Railways consulted possesses a locomotive testing plant; on the other hand, dynamometer cars are used by the *Italian, Czechoslovak, Yugoslav and Rumanian State Rys.*

* * *

PARTS ONE AND TWO.

Steam locomotives of the usual type and of new types.

In 1933, the *Italian State Rys.* carried out for a short period trials with a turbine locomotive on the Belluzzo system; these tests were stopped through a serious mechanical failure.

The locomotive in question was one of the 685 class, with a boiler having a working pressure of 16 kgr./cm² (228 lb. par sq. in.), the power being 1 600 E.H.P., and the usual piston engine being replaced by a turbine. The turbine drove the coupled axles through a double reduction gear and outside rods.

The non-condensing turbine running at 7 000 r. p. m. was of the impulse type degree of approximation will be maintained in time and under test conditions. four segments, fed as desired by four valves. For back running there were two

valves acting in parallel on the distributor for feeding three rotors driving the same axle as in forward gear.

The exhaust was of the usual type; the running gear, boiler, and tender were not altered in any way, and the conversion did not make any appreciable difference in the weight.

The running tests were few in number as owing to heating of the main shaft thrust bearings, part of the blades of the rotor wheels came adrift. These tests were sufficient to show that the steam consumption was much higher than with the ordinary locomotive of the same type, even at the most favourable speeds of the turbine. The maximum power was consequently much lower.

As regards starting, the maximum available power of the turbine locomotive was some 30 % less than that of the piston type, which could not be accepted, whilst in back gear the tractive effort was completely inadequate.

According to the opinion of the designer, very fundamental alterations would have had to have been carried out, such as the use of a variable drive (Wilson type gear), but for reasons for which the *Italian State Rys.* were not responsible, the experiment was abandoned.

Dynamometer car trials are now being carried out on a *Franco* type locomotive (fig. 1) obtained by altering one of the 670 class locomotives, now out-of-date, which lent itself however to rebuilding.



Fig. 1. — Franco locomotive undergoing tests on the Italian State Railways

Another Franco locomotive was built in Belgium, in 1934, by the Tubize Company works, at Nivelles, for the Belgian Franco Locomotives Syndicate, but this was a very heavy locomotive (240 tons) with a very high tractive effort, and consisting of three units. But the present case is interesting from another point of view : this was an endeavour to study the possible advantages of the new system for medium powers and on locomotives already in service.

The principle of the Franco system is very simple : it consists in feeding the boiler with water already raised to a temperature of 150 to 160° C. (302° to 320° F.) by means of the gases leaving the smoke tubes. The water is also previously heated to some extent by exhaust steam as in normal feed water heaters. Figure 2 shows the general arrangement of the boiler of the locomotive in question.

The tests of this locomotive have only just been started and consequently are only of a preliminary nature; no definite figure on its efficiency, therefore, is available. It is possible, however, to state that with a practically standard blast pipe the evaporation is much greater than on the original locomotive, and is even more than is really required; as the way the grate is fired does not vary much, the ratio between the water evaporated and the fuel burnt is much higher than in the standard type, and the final result is some improvement in the boiler efficiency.

It may be pointed out in this connection that a theoretical value approximating the true one can be built up synthetically.

Elementary or partial balance-sheets can end in errors or in sums of errors; it is better, therefore, to follow the following argument :

The Franco locomotive differs radically from the classic type, seeing that the temperature of the combustion gases on leaving the chimney is much lower

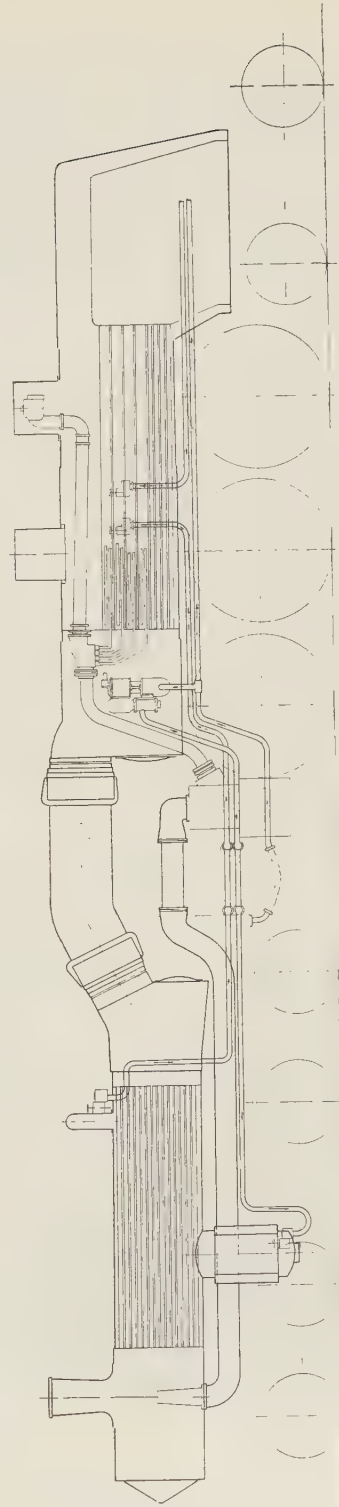


Diagram showing the steam generator of the Franco locomotive under test on the Italian State Railways.

Fig. 2.

than usual. This difference is some 100° C. (180° F.) or a little less; let us take 90° (162 F.) as its value when running under working power.

The temperature in the firebox above the grate being equal to the temperature in the other locomotives, the overall saving in running must be that given by the formula :

$$\frac{90}{1100} \times 100 = \approx 8\%$$

if we take the temperature in the firebox in the area immediately above the fuel when the fire is burning well as 1100° C. (2012° F.).

No other factor of any importance can improve the overall heat balance-sheet of this locomotive compared to the standard type fitted with an exhaust steam feed water heater, of the normal type. This value can therefore represent the maximum saving of fuel under normal working conditions.

Considered from the operating point of view, this value should be slightly reduced for the following reasons :

— When running at reduced power — which frequently occurs on hilly lines — the difference of the thermal level, corresponding to the heat recovered will certainly be less than 90° C.;

— When running with the regulator shut the quantity of heat units which can be recovered in the smoke tubes of the secondary boiler used as a feed water heater is very small; sometimes there may even be an exchange of heat in the reverse direction, i.e. from the hot water to the gases;

— The above mentioned economy only relates to the fuel burnt when running, i.e. only 75 to 80 % of the coal consumed by a locomotive in ordinary working; it is also necessary to take into account the standing and lighting up times, during which the percentage of coal is almost a constant value little affected by the type of boiler.

It is not possible to give any accurate figure as to the extent the saving claimed is reduced in this way; the above shows, however, that all we can count on is a very modest amount. When this result is related to the relatively cheap price of coal the saving obtained per unit and per annum is small. In addition it is necessary to take into account the cost of building a Franco locomotive which is higher than that of an ordinary locomotive of equal power.

Against this, an increase in the savings can be got if we consider that the main boiler fed with water already under working pressure and at the temperature of 150 to 160° C. has nothing to do but turn the water into steam and remains practically free from deposits, the salts contained in the water tending to fall out in the heating boiler. This facilitates maintenance of the parts exposed to the highest temperatures and consequently gives greater use of the locomotive, as well as improves the heat transfer coefficient between the combustion gases and the water.

In certain cases, for example when using very hard water with very small boilers at high rates of evaporation — which frequently happens on colonial railways — this consideration can become very valuable owing to the violent ebullition and priming. This state of affairs which is always very harmful interferes with the proper maintenance of the superheater if chlorides are found in the water to any great proportion.

In conclusion, even if the overall financial balance-sheet is good, and it only can be to a very small extent, the construction of locomotives of the Franco type is only justified under the following conditions :

On important Railways :

(a) for goods traffic, the existence of zones with heavy currents (such areas providing mineral traffic) or when the introduction of a few very long and very

heavy trains represents the most economical and best solution. These lines, in addition, normally require double heading.

The same conditions should exist for passenger traffic, i.e. double heading in order to increase the weight of the trains, by reducing their number (which is contrary to the traffic tendencies) or to increase very considerably the speed of the existing trains in order to use the high power available. In this case we usually come up against the regulations on the maximum allowable speeds on the lines in question; in addition it would be necessary to make sure the Franco type will be suitable for very high speeds;

(b) having abandoned the idea of electrifying the lines;

(c) having no surplus locomotives.

On secondary lines :

(d) Owning lines of narrow gauge or with light track with very steep gradients and small radius curves, carrying relatively heavy trains : the case when locomotives of the *Mallet* or *Garratt* types are used.

The Franco *system* is suitable for the kind of locomotive with a power tender with a limited axle weight which will take curves easily, with good evaporative power, or in other terms — apart from the particular conditions already given concerning the water — meeting the requirements of many colonial railways in hilly country, such as those of Italian East Africa.

* * *

Now that we have reviewed the locomotives of new type built since 1930 in the countries covered by our report, a few considerations of a general nature may be of interest.

The constant efforts made to improve the efficiency of the equipment for transforming thermal energy into work obvi-

ously have a direct repercussion on the investigations and projects relating to the particular heat engine represented by the steam locomotive. In this kind of engine the practical difficulties that have to be overcome before theoretical schemes can be made to work, relatively to similar difficulties with the fixed plants, are of a quite particular nature in view of the necessity for keeping the engines within precise and invariable limits of the constructional gauge, and the cost of construction and the weight per unit of power within the limits allowable with a mobile machine — particularly if intended to haul loads on lines on gradients — and finally to provide a motor with those characteristics of flexibility, and variability of working power considered essential in railway work.

The new technical tendencies are always based on the classic principles of thermodynamics, according to which the efficiency of a heat engine increases with the temperature range and the difference in pressure between the boiler and the condenser; having exhausted almost all the possible methods of using low exhaust pressures and temperatures which have been carried to the limits of practical possibility by using the very improved condensers of the stationary and marine engines, the tendency now is directed towards producing and using the steam at higher pressures and ever-increasing superheat.

In the particular case of the high-power locomotives (above 1 000 H.P.) it has not been possible to solve the problem of the use of condensers in a general and suitable manner, not even in the case of rotary engines, chiefly because of the difficulty of making light weight equipment of high thermal capacity; on the other hand the use of medium pressures and high temperatures is becoming more and more general, on locomotives of the normal type on which the boiler pressure exceeds 25 kgr./m² (356 lb. per sq in.) and reaches as much as 35 kgr./

properties of steam up to the critical point [abs. pressure 225 kgr./cm² (3 200 lb. per sq. in.), temperature 374° C. (705° F.), total heat in the steam 502 calories, (1990 B.T.U.)] it will be noticed that starting from the absolute pressure of 25 kgr./cm² (356 lb. per sq. in.) up to higher pressures, the curves of the total heat of the steam — in particular the limiting curve of saturation — change gradually, until an increase in pressure no longer corresponds to an increase in the heat of a unit weight of steam; it will be noticed on the contrary, that this heat decreases as one proceeds towards higher pressures.

The result is that, starting from this pressure, a gradual change takes place in the physical properties of the water vapour. Indeed, an adiabatic expansion without doing outside work (i.e. an expansion following a straight line parallel to the centre line of the entropies) which commences, for example, in the limiting saturation curve (dry saturated steam) produces at pressures lower than 25 kgr./cm² (356 lb. per sq. in.) a superheat of the steam as in the case of the vector *a b* (superheat due to expansion through a friction or HIRN spontaneous superheat). On the other hand, in the case of much higher pressures the same change produces a reduction in the quality of the steam which becomes lower than unity, i.e. humid vapour is produced as in the case of vector *a' b'*.

The first phenomenon pointed out above : reduction of the total heat in the dry saturated steam, is due above all to the fact that the reduction of the heat of evaporation is greater with the increase in the pressure than the increase in the heat of the liquid and makes it possible to use the heat better in the range of temperature available. In fact, if we consider the adiabatic expansion with outside work B'B which commences at 10 kgr./cm² (142 lb. per sq. in.) absolute, and ends with the pressure of the condenser at 0.1 kgr./cm² (1.42 lb. per

sq. in.) abs., it is immediately seen that this expansion uses less heat than that taken in the same expansion beginning at 50 kgr./cm² (712 lb. per sq. in.) absolute with the same total heat and ending at the same condenser pressure (segment AA'). This greater usable quantity of heat is measured by the segment AX.

The second phenomenon accompanying real positive transformations of heat into work, which cannot be adiabatic, shows us that the practical use of high pressures is in the zone of the diagram above the saturation curve if we wish to prevent either the steam dryness falling off without the steam doing any outside work, in other words that *the use of high pressures should always take place in conjunction with the use of superheated steam*. As the initial superheat temperature is increased in an adiabatic change, the curve relating to the exhaust pressure is obtained with a theoretically increasing total use of heat, a fact which increases the importance of superheating.

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The increase in the heat range between the boiler and the exhaust, obtained with the steam engine of a high-pressure locomotive, — compared with that of a locomotive using medium pressures — requires the subdivision of the driving power into two phases of high and low pressure (the need of a triple expansion is not felt seeing that, as we have already said, condensation must always be given up in the case of high-power engines, and consequently a free exhaust used), and also makes it necessary to take into account the advantages that can be obtained from the *intermediate superheating* of the exhaust steam, the usual practice in high-power stationary plant, to improve the total efficiency of the transformation of heat into work. An adiabatic expansion

left after doing this work, is used to heat the feed water of the high-pressure boiler by the regenerative process, well known in modern thermal plant — particularly in America — working at high pressures.

(a) *Initial superheat of the steam.*

In the case of high-pressure locomotives, as in fixed plant, the upper limit of the temperature to be obtained in front of the high-pressure engine, is always determined by theoretical and constructional reasons.

From the thermo-dynamic point of view, it must be pointed out that high pressures require a high superheat temperature if it is desired to prevent the steam from reaching too soon — i.e. at still too high pressures — the zone of wet vapour, with the well known loss of engine efficiency, due essentially to the variation of the physical state (from superheated steam to saturated steam) which takes place in the engine (high-pressure or low-pressure) before it has done the work expected from it. Examining the isothermal and isobar curves relative to superheated steam, it will be found too that increases in the temperature make it possible to use in the zone of superheated steam a smaller quantity of heat as the pressures increase, because if it is desired to maintain a high superheat temperature — after the first use of the steam at high pressure, as has already been said — an intermediate superheater, the object of which is to keep the steam well away from the saturated curve, must be provided. This second superheat can reach values higher than the first unless prevented by constructional or installation reasons.

However, the intermediate superheat as a rule reaches temperatures somewhat below those of the initial superheat. In addition to the value of the temperature which can be obtained in the secondary superheater and the satisfactory division of work between the two engines from the theoretical point of view, there is no

essential reason for limiting this initial superheat with the increase of the working pressure.

On the other hand, from the constructional point of view for high pressure locomotives, the superheat temperature is limited :

1. By the properties of the materials used for the boilers, and in particular by their elastic limits, conditions which, as is known, rapidly deteriorate with the increase in pressure and temperature. Modern metallurgy has succeeded in producing by suitable heat treatment iron alloys which make it possible to use under normal working conditions pressures of 200 kgr./cm² (2 840 lb. per sq. in.) and temperatures of 450 to 500° C. (842 to 932° F.).

2. By the characteristics of the engine used for traction purposes.

Up to the present we have only dealt with the heat engine in general without specifying whether it is the rotary type (turbine) or the reciprocating type (piston).

Tests have been carried out on locomotives with these two types of engine. But up to the present it has not been considered desirable to add to the experiments on high-pressure boilers those in connection with the application of turbines to railway work, as this method of traction still has big « unknown » factors, especially as regards the efficiency of such heat engines where conditions vary considerably at the start under load, at low pressure and maximum effort, as well as the difficulty of getting a satisfactory mechanical coupling between the turbine running at high angular velocities and the driving wheels of the locomotives. Consequently experimental applications of turbines on locomotives have been carried out so far with boilers of the usual type working at average pressures, such as 22 kgr./cm² (313 lb. per sq. in.).

The application to high-pressure piston engine locomotives having been limited, at least for the moment, the limit of temperature is obviously determined by lubricating necessities, and in consequence by the properties of the lubricants used, particularly as regards the device feeding the steam to the cylinders, the temperature in which is very close to that of the steam on admission.

Poppet valve gears on locomotives provide an ample range of cut-offs and enable the engine to run equally well in either direction; no lubrication of the valves is required, and they therefore seem the most suitable for high-pressure locomotives with high superheat temperatures. Under these conditions the difficult lubrication question is limited to the pistons, which working in steam at a temperature between that of admission and that of exhaust make it possible to use lubricants which do not stand up quite so well to high temperatures, in smaller quantities, required not only to lubricate the cylinders but also the piston valves. The latter condition makes it much easier to solve the problem of separating the oil in the case of intermediate superheat already mentioned.

In the tests carried on so far, piston valves have been used generally, in particular because the temperature of the superheat has never been much higher than 400° C. (752° F.) at which temperature lubricating oils for ordinary types of steam locomotives are satisfactory.

If a higher temperature is desired, for example 500° C. (932° F.), lubricating difficulties become so great that poppet valve gear has to be used on the reciprocating engine, at least in the case of the high-pressure side.

* * *

(b) *Double expansion and intermediate superheat.*

The theoretical diagram of figure 4 shows the division of the work into two

groups, high-pressure and low-pressure, with intermediate superheater, and should be modified if it is desired to obtain the actual diagram of the transformation of heat into work by introducing into it the actual *thermodynamic efficiency* factor of the engine.

It should be remembered that the actual shape of the adiabatic expansion curve does not follow the same parallel lines as the ordinates, as shown in fig. 4, but a curve following the natural direction of the increase of entropy as shown in figure 5 where the practical result actually obtained with one of the high-pressure locomotives tested is reproduced.

Consequently the *thermodynamic efficiency* R of an engine (for example the high-pressure in a compound engine) is generally defined as the ratio of the total heat A_0B_1 (fig. 5) used by the engine, to the quantity of heat A_0B_0 which would be used with a perfect engine (and consequently reversible) work on the Rankine cycle with the same pressure range :

$$R_1 = \frac{\text{range } A_0B_1}{\text{range } A_0B_0} = \frac{AM}{A_0B_0}$$

In a similar way beyond the intermediate superheating B_1M_0 the efficiency in the low pressure engine will be :

$$R_2 = \frac{M_0N}{M_0M_1}$$

In experiments with the high-pressure locomotives mentioned above, one gets an average value of $R = 0.74$ approx. in the high-pressure, and 0.72 in the low-pressure engine, so that the overall thermodynamic efficiency of the compound engine is :

$$R = 0.74 \times 0.72 = 0.53.$$

Even with these optimum values of the thermodynamic efficiency (very interesting because they relate to the engines of locomotives under varying working con-

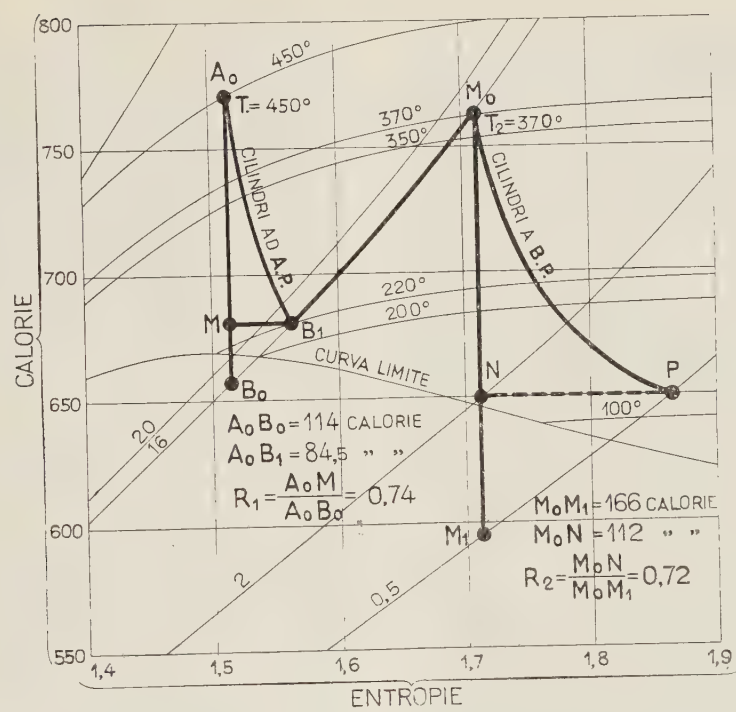


Fig. 5.

Note: Cilindri ad A.P. (a B.P.) = high (low) pressure cylinders.

ditions, and not condensing) the work in the two high and low-pressure groups is not and could not be equally divided easily in view of the limits imposed on the cylinder dimensions by the constructional gauge and the necessity for dividing the pressure range to suit the thermal conditions, which in turn are subject to certain constructional conditions.

To lessen this inequality of work, the best designed high-pressure locomotives have three cylinders with cranks at 120° with the same stroke as used on the medium pressure types (two outside high-pressure cylinders and one inside low-pressure cylinder as in the *Löffler* system, or one inside high-pressure cylinder and two outside low-pressure cylinders as in the *Schmidt* arrangement). Then too four-cylinder engines with two high-pressure and two low-

pressure cylinders arranged symmetrically, of the type already widely used on very powerful locomotives (*Schmidt* system high-pressure locomotives of the *P.L.M. Rys.*) have given good results.

Thanks to these engine arrangements, a sufficiently uniform driving torque at the wheels of the locomotive can be obtained quite easily even with unequal division of work in the engine groups. The total weight of the coupled wheels can be used for adhesion with, in consequence, a high average adhesion factor.

* * *

(c) Free exhaust to atmosphere.

The free exhaust to atmosphere of steam having done its work in the low-pressure engine of a high-pressure loco-

motive is a feature peculiar to this type of heat engine. It is the usual practice on the most notable types of engines built for main-line work, and is the direct consequence of the general abandonment of condensing for the reasons given earlier. These reasons, however, may not apply to less powerful locomotives. Consequently a condenser of limited weight and size may be used without excessive cost. This condenser will deal with the exhaust steam from the cylinders after it has passed through the various auxiliaries in series with the condenser.

These auxiliaries use the remaining heat in the exhaust steam and thereby increase the overall thermal efficiency, and by reducing the amount of heat to be absorbed at the end of the cycle relieve the condenser.

When there is no condenser, the exhaust steam is used to create the blast to which purpose it lends itself in a most satisfactory way in the case of an engine having to work under such varying conditions as a locomotive.

The free exhaust of the steam to atmosphere takes place through the cone or system of cones of the usual blast pipe which make up the ejector providing the artificial draught required. As is known, this particular feature of the locomotive is light, simple and reliable, and regulates the combustion automatically, seeing that the vacuum at the base of the chimney — the resistance to the passage of the gases through the tubes and grate does not vary — changes with the rate of working of the engine. This vacuum thus conditions the evaporation of the boiler which increases with the demands for steam, and consequently with the quantity and physical properties of the exhaust steam.

Part of the exhaust steam may be diverted to a feed water heater when the usual fixed blast pipe top is used, without spoiling the draught. From this aspect too the fixed blast pipe can be

applied still successfully on locomotive of a type quite different from that for which it was designed originally. In recent years the fixed blast pipe has undergone fundamental changes which have made it more efficient, either as an ejector, or indirectly, with equal efficiency, by reducing the back pressure and thus relieving the cylinders. The free blast acting as an ejector is equally suitable therefore for powerful modern high-pressure locomotives.

* * *

Fundamental features of high-pressure locomotives.

The most striking characteristic common to the two best known types of high-pressure high-power locomotives is that the available range of temperature is used in two distinct parts, both in the engine, and in the boiler unit consisting of two boilers connected together thermically in tandem, i.e. in such a way that the residual heat from the first is used in the second.

The primary or high-pressure boiler feeds the high-pressure engine, whilst the second boiler (the working pressure of which is the same as that of present-day steam locomotives of the normal type), using either wholly or partly the heat of the steam exhausted from the high-pressure cylinder, supplies steam to the low-pressure engine.

The primary boiler is heated directly by a coil containing the fluid (water vapour) heated directly by the flames. *This boiler is therefore not in direct contact with the fire*, which obviously simplifies its construction by diminishing the stresses to which its walls are exposed.

As characteristic types of the indirect transmission of the heat to the primary generator we may mention the high-pressure locomotive boilers on the *Schmidt* and *Löffler* cycles. In the first system,

the high-pressure and low-pressure steam is mixed and then exhausted to atmosphere; in the other the high-pressure steam is always kept separate from the low-pressure. The *Löffler* cycle, as applied to the first test locomotive of the *Deutsche Reichsbahn*, can therefore be considered as a true *binary cycle using two distinct fluids*. Actually the same fluid (water vapour) is used, but in two different physical states, to obtain from the difference of behaviour of the fluid in the two states considered a difference of thermodynamic efficiency which has a direct influence on the improvement of the overall efficiency of the heat engine.

This being so, there is nothing to prevent, at least in theory, the *Löffler* cycle being used, with two different fluids, so that through the closed primary cycle the fluid circulated is not water vapour at very high pressure but a similar fluid or one even better thermodynamically. The idea of such a boiler is not new, especially for stationary purposes, but it is being used experimentally for the first time in railway work in the binary cycle of the *Löffler* locomotive.

When proposing to increase the efficiency of the locomotive by the use of high pressures [up to 120 kgr./cm² (1 706 lb. per sq. in.) and above] the author finally got out an arrangement by which the high pressures were replaced by much more reasonable pressures in the primary cycle by circulating a suitable fluid, such as mercury, through them.

The function of the condenser being filled by the secondary generator, the reciprocating (piston) high-pressure engine could be a rotary engine (turbine) whilst leaving to the reciprocating low-pressure engine the duty of meeting the requirements of flexibility and variation of power required in railway work.

The simultaneous use on a locomotive of the two types of engine, rotary and reciprocating, could be adapted to the starting conditions, in which the consi-

derable value of the instantaneous motive effort must be added to the need for properly regulating the driving torque, which is rather irregular in the piston engine, and might be corrected and improved by the turbine. This rotary engine in this case may be able to work under good conditions as there may be no condenser.

The idea of uniting the two completely different characteristics of the turbine engine and the reciprocating engine in railway work is not new; it was considered and discussed at the 1930 Madrid Congress, when dealing with a new type of locomotive in which, however, the turbine was only used for low-pressure working.

Consequently, the above theoretical arguments show that a definite thermal improvement of the steam locomotives may yet be found in this field, the limits of which are far from being known.

The undeniable attraction of the study of thermodynamic cycles at high pressure and expansion carried to great lengths explains the great interest these ideas raise in the railway engineering circles. A glance at the locomotives built throughout the world, however, shows a certain slacking off in the tendency to build locomotives of the types mentioned, high-pressure, turbine, etc., a tendency which, nonetheless, seems to open the field to other interesting designs full of promise for the future, as was recorded at the last Railway Congress.

The question then arises for what reasons did this slowing down occur, if only in the experimental examples, after the great interest shown in the technical press throughout the world in the first specimens which were built? Has the problem become stationary, or have there been no further trials in recent years, or have the alterations to the units in existence shown no improvement?

Without doubt the difficulties encountered when building such complicated and delicate engines and getting them into

working order have contributed to this holding up of progress, and also the cost of maintenance of very-high-pressure plant; the use of condensers with turbine engines — although very important thermodynamically — cannot use up the considerable amount of heat in the exhaust steam owing to the impossibility — without giving up a large percentage of the financial saving — of fitting adequate and not too heavy coolers on the locomotive. The present financial railway crisis may also have made it desirable to hold up costly alterations and experiments resulting in no immediate saving.

Without entering into details or without making any forecasts on the future development of the various tendencies, in view of the complexity of the subject, we may however conclude that just as all technical improvements must give tangible financial savings, the improvements in question should be carefully estimated especially as regards the promised economies.

Their essential object is to reduce the cost of fuel per unit of work developed by locomotives and to increase their power.

The cost of fuel in railway working is generally some 20 % of the total traction costs.

Consequently if a considerable reduction in the fuel cost means increases in the expenditure under other headings, for example the remuneration of the considerable capital required to build the engines and for their periodical repair and current maintenance, as well as that due to their lower availability owing to more frequent repairs, it is probable that the final financial balance-sheet can only just be balanced or even be adverse.

In addition, all new complications of a mechanical kind give rise to operating difficulties by increasing the likelihood of failures, so that the new locomotives ought to be perfected down to the smallest detail before going into normal service in which regularity and safe work-

ing are of much greater importance than questions of economy.

The specific power could be definitely increased by the adoption of the new types, but the economic considerations developed above affect goods traffic rather than passenger traffic, modern passenger locomotives of the usual type being already sufficiently powerful for the normal speeds.

For very high speeds, other light types of traction have been evolved which meet this kind of traffic much better. It is neither possible nor opportune to alter the tracks in such a way that locomotives of ever increasing weight can be worked over them at ever higher speeds, with the degree of safety required for public railway services.

* * *

To end this chapter we think we can put forward the theory that for many years to come the evolution of the steam locomotive on the railways will lead to the use of the moderate pressures of some 25 to 30 kgr./cm² (356 to 426 lb. per sq. in.), which will improve the efficiency and the specific power usefully, without affecting the maintenance conditions too seriously.

These advantages and detail improvements made, make the locomotive of the classic type very much alive, and enable it to meet present requirements and those of the near future quite satisfactorily.

It is possible that in the future mainline steam traction may find high pressures a satisfactory solution, not in connection with the designs dealt with above, but through an evolution of the principles now applied on many types of steam railcars.

There is nothing to prevent boilers with high rates of evaporation reliable and self-regulating, and high-speed engines, after the constructional and other drawbacks inherent in new designs have been

eliminated, from being developed from small units into units suitable for medium-sized and heavy locomotives.

* * *

PART THREE.

Locomotive tests.

A. — Tests on fixed test plants.

Neither the *Italian State Rys.* nor any of the other Railways dealt with in this report possess a fixed test plant; we will therefore pass directly on to Chapter B.

B. — Running tests with brake locomotives.

CHAPTER I.

Dynamometer cars.

The first Italian dynamometer car was built in 1904. It was fitted with Amsler dynamometer equipment of the spring type, then usual.

The number of measuring instruments permanently installed in the coach and of auxiliary fittings was gradually increased until 1930, when a Siemens apparatus for recording a number of curves, and a combustion gas analyser were purchased, and the old dynamometer car was replaced by a new and longer steel vehicle in which the existing equipment was installed.

The steadily extending electrification of the Italian lines during recent years showed the need for equipment for making electrical measurements; in addition the old dynamometer, which could register a maximum pull of 12 tons, was inadequate for the powers developed by the new locomotives. It was then decided to adapt the equipment to the new requirements, by purchasing a new dynamometer and other modern apparatus. This equipment was fitted in the existing car, of which figure 6 is an exterior view.

This metal coach carried on 4-wheeled bogies, and weighing about 51 tons, includes a compartment for the equipment, two sleeping compartments, a photographic room, and a service room with a heating boiler, tools, etc.

The measuring devices permanently fitted in the coach include the following:

- (a) dynamometer and auxiliaries;
- (b) device for recording the working conditions of the steam locomotives;
- (c) device for recording the working conditions of the electric locomotives, with oscillograph.

In addition there is a large amount of other apparatus, which are only fitted when required, to prevent the car being overcrowded unnecessarily.

a) The dynamometer supplied by Messrs. Amsler, of Schaffhausen, is of the hydraulic type and records traction and compression forces in both running directions.

The forces are transmitted as usual

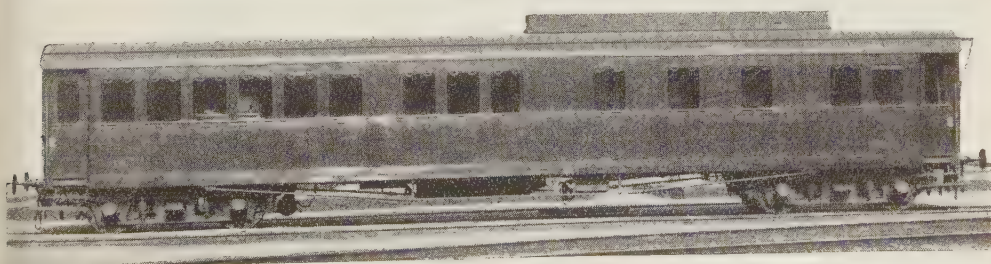


Fig. 6. — New dynamometer car, Italian State Railways.

through a draw-bar or thrust blocks to a piston carried in a cylinder filled with oil, secured to the frame. This cylinder when in use receives varying loads which it transmits by means of suitable pipes to another and smaller cylinder, the piston of which, in moving, has to overcome the resistance of a minutely calibrated spring. In accordance with the ratio of the areas of the two cylinders the deflection curve of the opposing spring, the pen connected to the small piston traces the instantaneous value of the locomotive drawbar pull to a suitable scale.

This piston being of the differential type, any one of the three scales can be used as desired by means of the distributor valve which opens the connection to the corresponding piston diameter.

In the event of the load being applied any length of time, in the same direction, any leakage is automatically made good.

The draw-bar hooks and thrust blocks are coupled to a kinematic equalizer so that the car can be coupled closely to the locomotive, without affecting the working of the dynamometer. A Westinghouse friction draft gear is fitted between the equalizer and the dynamometer, so that the forces can be transmitted to the frame of the car directly when the dynamometer is not to be in use, by inserting a pin at a given point in the drawgear.

The continuous speed recorder and indicator is of the type adopted by Messrs. Amsler since many years. Its design is based on the angular variation between the succeeding positions of the instantaneous axis of a ball, these variations depending on the ratio of the peripheral speeds of two orthogonal rollers which drive the ball by frictional contact, one being driven at a constant angular velocity by clockwork, and the other revolving at a speed proportional to that of the car. A second pair of rollers in the plane through the centre of the ball, at right angles to the plane

through the centres of the other pair, bear on the same ball and follow any changes in its axis of rotation. The recorder makes the speed in the dynamometer car chart to one of three scales, i.e. up to 50, 100 or 150 km. (31, 62 or 93 m. p. h.) an hour.

A Teloc speed recorder for speeds up to 225 km. (140 m.) an hour is also provided.

The draw-bar pull is measured and recorded by means of an Amsler ball type integrator, the diagram being inverted as usual for recording on a paper band, so that the chart is kept within the dimensions of the paper.

The *potentiometer* is also a differential of the Amsler type, based on the same principles as the tachometer. In this case also the value (indicated and recorded independently) is proportional to the tangent of the angle between the centre line of the constant speed roller and the axis of rotation of the ball.

All the recorders in connection with the dynamometer make a record on the 646 mm. (27") wide chart, the movement of which can be regulated in terms of time and distance at will.

The speed can be 20, 100 or 600 mm. per kilometre travelled, or 1, 5 and 30 mm. per second. The change can be made whilst running without interrupting the recording.

The distances in kilometres and the time in 6-second intervals and one-minute intervals are recorded on the chart.

As figure 7 shows, the indicators are grouped together on the measuring table as well.

The dynamometer can stand a load of 45 000 kgr. (99 200 lb.) in pull or compression. This load was increased to 55 t. (121 250 lb.) during the inspection tests.

Below are given certain interesting data on the dynamometer and other readings taken.

Dynamometer for traction and compression, maximum ordinate: 100 mm.

$$\text{Three scales — maximum pull . . . } \left. \begin{array}{l} 6 \text{ t.} \\ 18 \text{ t.} \\ 45 \text{ t.} \end{array} \right\} 1 \text{ mm.} = \left\{ \begin{array}{l} 60 \text{ kgr.} \\ 180 \text{ kgr.} \\ 450 \text{ kgr.} \end{array} \right.$$

Totaliser of work done, maximum ordinate: 75 mm.

$$\text{Three scales } 1 \text{ mm.} = \left\{ \begin{array}{l} 6\,000 \text{ kgrm.} \\ 18\,000 \text{ kgrm.} \\ 45\,000 \text{ kgrm.} \end{array} \right.$$

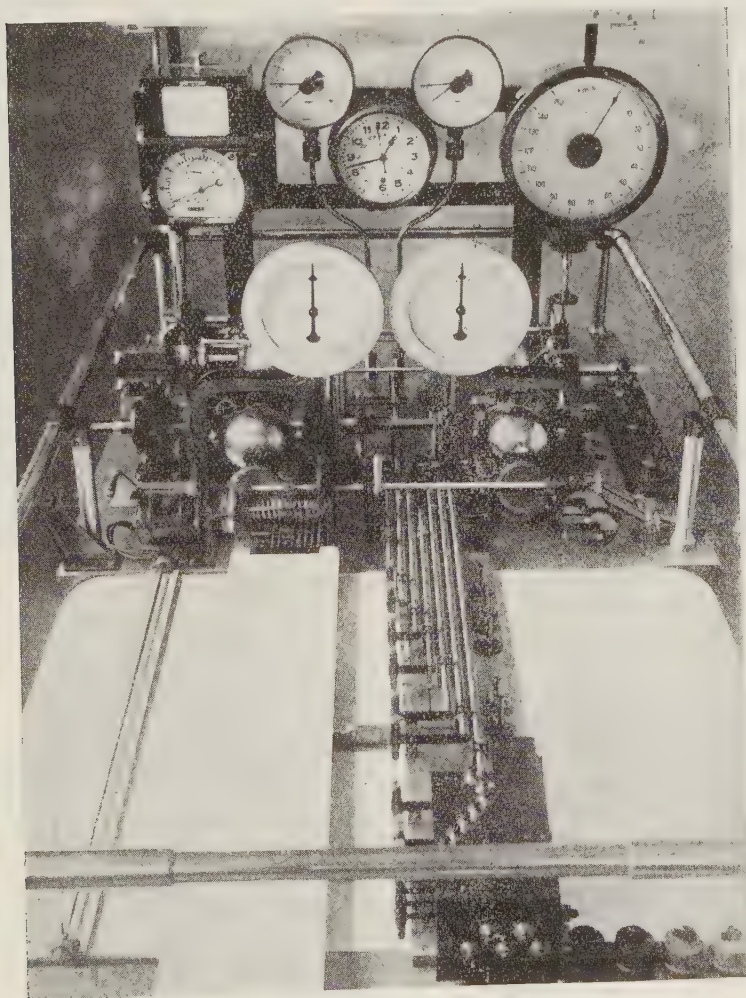


Fig. 7. — Measuring instrument table of dynamometer car, Italian State Railways.

Speed indicator, maximum ordinate : 50 mm.

Three scales — maximum speed . . .	50 km./h.	1 mm. =	1 km./h.
	100 km./h.		2 km./h.
	150 km./h.		3 km./h.

Potentiometer, maximum ordinate : 100 mm.

Maximum effort	45 t.	18 t.	6 t.
Two scales for each scale of effort . . .	1 mm. =	120	48
		240	96
			16 H.P.
			32 H.P.

The measuring instrument table also includes an indicator of the distance travelled to two scales, from which the section of line run over can be identified by drawing a gradient section of the line

to the proper scale.

The following tolerances in the record made by the above apparatus were laid down when the equipment was ordered :

Tractive and compression efforts :

- difference F_1 between the pressure of the oil acting on the measuring piston, and the theoretical pressure corresponding to a known load applied to the piston of the dynamometer, i.e. the difference attributable to the frictional resistances of the latter $F_1 < \pm 1 \%$
- the difference F_2 between the value of the force recorded and that of the force calculated in terms of the oil pressure, i.e. the difference due to errors in the calibrated springs or to the frictional resistances of the measuring pistons $F_2 < \pm 1 \%$
- difference F between the effort recorded and the theoretical effort, i.e. the sum of the partial errors already mentioned $F < \pm 2 \%$

For the secondary values based on the tractive effort, i.e. for the work done :

- the difference L_1 between the work recorded and the work corresponding to a force also recorded on an exactly given length of paper, i.e. error due to the ball integrator $L_1 < \pm 1 \%$
- difference between the work recorded and the actual work $L < \pm 3 \%$

For the tertiary values (power) :

- difference P_1 between the instantaneous power recorded and that corresponding to an effort recorded on a given length of paper during an exact interval of time, i.e. sum of the errors due to the integrator for the work, and to the ball differentiator for the power $P_1 < \pm 2 \%$
- difference P between the instantaneous power recorded and the actual power $P < \pm 4 \%$

For the Amsler speedometer :

- difference V between the speed recorded and the actual speed measured relatively to the time taken for a given run (paper unrolled) i.e. error due to the ball differentiator $V < \pm 1 \%$

In addition the errors of the instrument due to possible play in each mechanism must not exceed a maximum of $\pm 0.5 \%$.

The above tolerances are guaranteed for

any outside temperature provided that the temperature of the dynamometer car is always between 0° and 30° C. (32 and 77° F.), like that of the instruments.

The checks carried out when inspect-

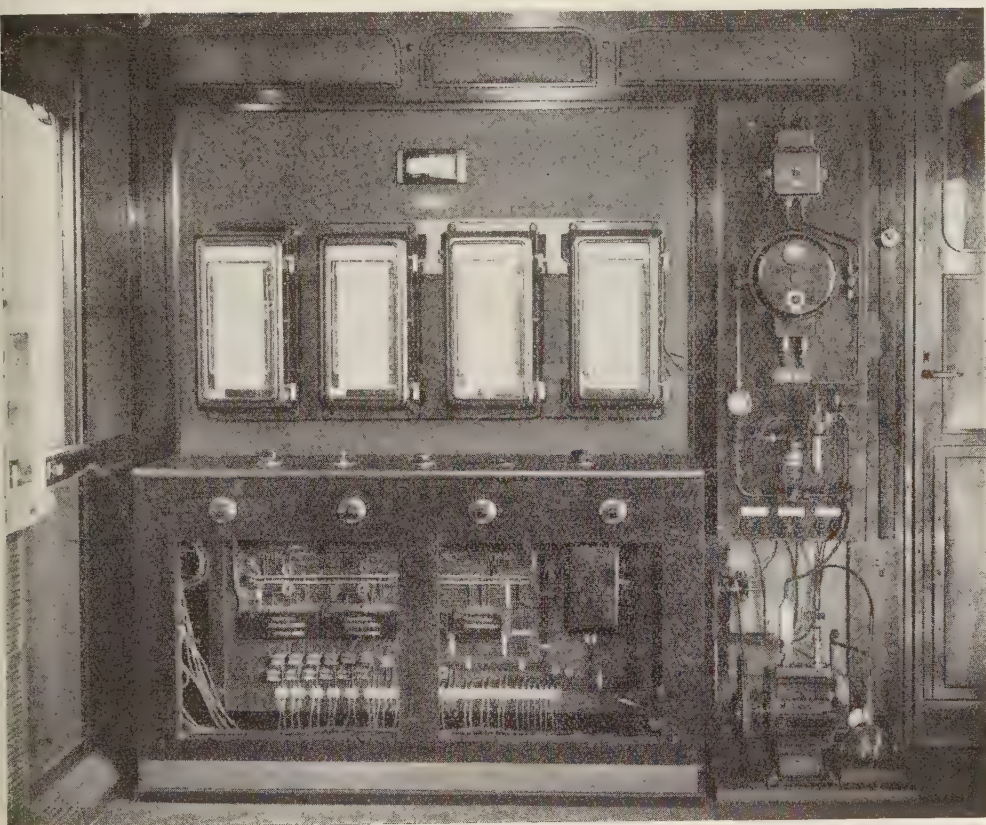


Fig. 8. — Siemens instruments in dynamometer car, Italian State Railways.

ing the equipment showed errors much smaller than the allowed tolerances; it is not yet possible to say if this optimum degree of approximation will be maintained in time and under test conditions.

For testing the equipment of the car, means are provided for putting definite loads on the oil.

(b) As regards measurements of the working conditions of steam locomotives,

the following apparatus are fitted in the car permanently :

- a Siemens recorder;
- two Leeds & Northrup pyrometers;
- two boiler feed recorders;
- a recording meter for the steam used for train heating.

The Siemens apparatus (fig. 8) consists of four multiple recorders with the following primary elements :

- pressure gauge for pressures from 0 to 20 kgr./cm² (284 lb. per sq. in.);
- pressure gauge for pressures from 0 to 20 kgr./cm² (284 lb. per sq. in.);
- two-scale thermometer varying from 0 to 250° C. (32 to 482° F.) and 200 to 500° C. (392 to 932° F.).

No. 1.

- | | | |
|---|---|---|
| No. 2. | { | pressure gauge for pressures from 0 to 2 kgr./cm ² (28 lb. per sq. in.); |
| pressure gauge for pressures from 0 to 6 kgr./cm ² (85 lb. per sq. in.); | | |
| thermometer for measuring from 0 to 150° C. (32 to 302° F.). | | |
| No. 3. | { | thermometer for measuring from 0 to 250° C. (32 to 482° F.); |
| thermometer for measuring from 0 to 250° C. (32 to 482° F.); | | |
| pyrometer for measuring from 0 to 800° C. (32 to 1472° F.). | | |
| No. 4. | { | pyrometer for the maximum value of 1 600° C. (2 912° F.). |
| CO ₂ recorders, for 0 to 20 %; | | |
| CO + H ₂ recorders, for 0 to 4 %. | | |

The thermometers are of the variable resistance type, i.e. composed of a metal resistance inserted in a branch of a Wheatstone bridge connected to a galvanometer. The variation in ohmic resistance in the circuit as a function of the temperature unbalances the bridge and the galvanometer gives the corresponding indication in degrees centigrade, which is recorded at the same time by a flap valve mechanism.

The two thermo-electric couple pyrometers are: one of the iron-constantan type (for measurements in the smoke box) and the other of a platinum-platinum-rhodium-couple. The currents produced by thermo-electric couples are carried directly to the galvanometer, i.e. without passing through the Wheatstone bridge.

In the case of the pressure gauges the principle of the variation of the ohmic resistance in a circuit fitted, like the thermometers, with a Wheatstone bridge, is used, but in this case the variation is given by a small brush fixed to the finger of the pressure gauge fitted on the locomotive, which slides over a metal spiral, thus inserting more or less resistance, proportional to the position of the finger, i.e. to the value of the pressure.

The combustion gas analyser is designed on an essentially physics base. The gases leaving the smoke box are drawn in by a pump through a series of filters and arrive, at a speed regulated by a calibrated injector, to the two transmitters. That of the CO₂ apparatus (fig. 9), based on the difference of ther-

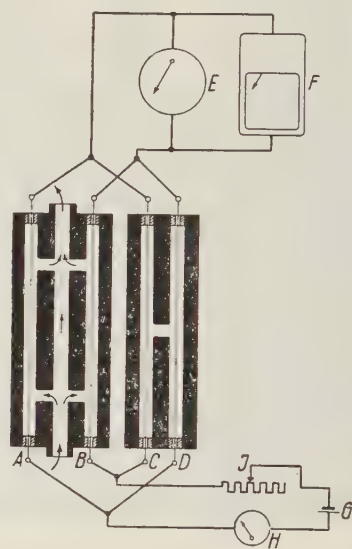


Fig. 9. — Diagram of the CO₂ measuring device.

mic conductivity of the different gases, is formed of platinum wire heated by an electric current of known intensity, which is brought into contact with the combustion gases. These gases, owing to the variations in their composition, produce a variable dispersion of the heat, i.e. modify the temperature and consequently the resistance of the wire, which is part as usual of a measuring bridge.

The other apparatus (fig. 10), intended to determine the relative quantity of gases still combustible, is also formed of a platinum wire electrically heated and

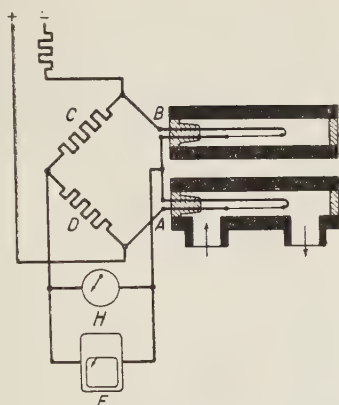


Fig. 10. — Diagram of the CO + H₂ measuring device.

brought into contact with the gases. By catalytic combustion, these gases subsequently heat the wire, which in this

- | | |
|--|---|
| — for the recorders coupled to the thermometers or pressure gauges | ± 1 % of the maximum value of the scale +
± 1 % of the instantaneous value. |
| — for the primary elements : | |
| resistance thermometers | ± 0.5 % of the indicated value. |
| thermo-electric pyrometers | ± 1 % of the indicated value. |
| pressure elements | ± 2 % of the value of the maximum scale
and in addition ± 1 % for the electrical transmission parts. |
| — for records in connection with the analyses of the combustion gases : | |
| for the CO ₂ | ± 2.5 % |
| for the CO + H ₂ | ± 10 % |

When testing the instruments with the vehicles stopped, the actual errors in the measurements were smaller than the tolerances given above. When the test is made at a high speed, these limits are not always maintained as regards each particular item, owing to the oscillations of the fingers of the recording galvanometers. However the diagrams give satisfactory results on the whole.

The apparatus for analysing the combustion gases is very useful for following and if necessary controlling the firing; it should be pointed out in this connection that it is not possible to expect

case too is a branch of a Wheatstone bridge.

The two apparatus are provided with comparison chambers, i.e. other cells with platinum wire in pure air to avoid measuring errors due to particular atmospheric conditions.

In each recording galvanometer the circuits are grouped in threes, and the various curves of different colours are drawn by dots. The inscription is made every 10 seconds so that the successive dots of a particular curve are recorded every 30 seconds.

The chart moves in proportion to the time 120 mm. per hour; if need be, signs can be marked simultaneously on all the bands by pressing a button.

The tolerances allowed for measurements with the Siemens apparatus are the following :

- | | |
|---|-------------------------------|
| ± 1 % of the maximum value of the scale +
± 1 % of the instantaneous value. | |
| ± 0.5 % of the indicated value. | |
| ± 1 % of the indicated value. | |
| ± 2 % of the value of the maximum scale
and in addition ± 1 % for the electrical transmission parts. | |
| ± 2.5 % | } of the maximum scale value. |
| ± 10 % | |

in ordinary working the tolerances being always exactly maintained, as this would mean frequently calibrating and replacing the cells containing the platinum wires.

The boiler feed is measured by two hot water meters (fig. 11) built by Messrs Siemens. These are of the oscillating type and measure the volume of water which, when passing through the measuring chamber, moves a disc. At each revolution this disc passes a quantity of liquid equal to the useful capacity of the said chamber.

These meters are always fitted on the

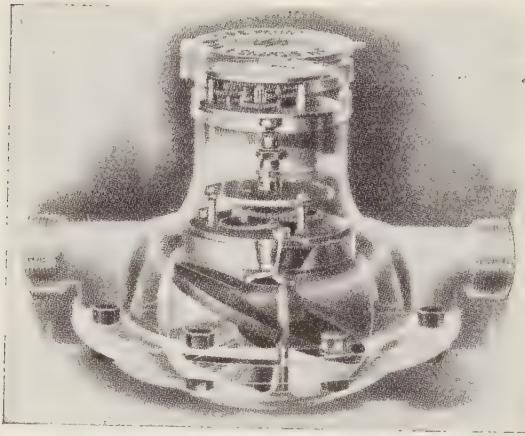


Fig. 11. — Siemens hot water meter.

delivery pipe of the injector or the feed water heater, because if they were fitted on the arrival side, a weight of water at least equal to a head of 2 m. (6.56'), which would be difficult to arrange on a locomotive.

The successive values indicated on a dial above the meter are recorded by an electric transmission on a paper band which moves in proportion to the time.

The maximum diameter of the pipe in which the meter is inserted is about 80 mm. (3 1/8"); the maximum water pressure is 20 kgr./cm² (284 lb. per sq. in.), and the normal rate of delivery is between 2 and 10 m³ (440 and 2 200 Br. gall.), with a permissible maximum feed of 13.5 m³ (2 970 Br. gall.) per hour for a short time.

The values recorded are guaranteed to within $\pm 2\%$ over the usual range of feed; in actual working the variations are less than this amount.

In this case of tests carried out with steam-heated passenger trains, a variable-orifice Bayer-Siemens measuring apparatus is fitted on the main steam pipe of the dynamometer car.

This Bayer apparatus (fig. 12) consists of a container with a measuring cone in which a float carrying a weight can move freely in the vertical direction.

The steam passes through the conical orifice from the bottom upwards and raises this float which opens an annular passage corresponding to the quantity of steam, whilst the pressure drop is balanced.

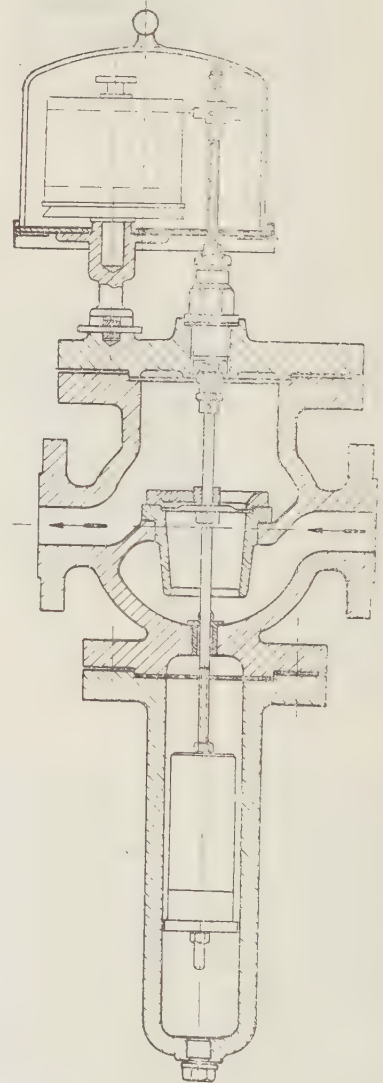


Fig. 12. — Bayer-Siemens meter for measuring the steam used to heat the feed water.

ced by the weight mentioned above. The measuring cone is so designed that there is always a linear relation between the quantity of fluid to be measured and the movements of the float; the latter is connected by a spindle to a recording pen which makes a continuous record of the variations in output on a paper chart, the movement of which is proportional to the time.

This apparatus will measure up to 700 kgr. (1 540 lb.) of steam per hour, at a maximum pressure of 13 kgr./cm² (185 lb. per sq. in.) and a temperature of 300° C. (572° F.), within $\pm 2\%$ between 5 % and 100 % of the maximum output, according to the usual temperature and pressure conditions of the steam used for heating the train.

Besides the Siemens recorder to which certain primary elements are connected — generally of the electric variable resistance type — the dynamometer car is fitted, for heat measurements, with two recorders, each making a double curve, and an indicator, all of the potentiometer type, built by Messrs. Leeds & Northrup, of Philadelphia. This system has the advantage of being quite independent of the ohmic resistance of the pyrometric circuit, as the electromotive force set up in the hot couple is not measured directly, but by balancing it against an opposing electromotive force of an exactly known value, i.e. on exactly the same principle as the ordinary direct-current potentiometers used for measuring differences of potential.

Figure 13 shows the wiring diagram. When a service battery B and a rheostat E are available, it is easy to get between points M and N (ends of the potentiometric circuit) a definite potential drop corresponding to the order of magnitude of the measurements to be made, for example one volt. A standard battery is used to make sure the difference of potential remains within the desired limits. The current starting from B, arriving at M, consequently passes through the cir-

cuit M.T.O.N, provided the opposing current, i.e. the current set up by the thermo-electric couple T, dependent upon the resistance of two circuits ending at points M and O is not stronger. The galvanometer, however, will indicate the passage of a current, except in the event of the two currents not being balanced, i.e. the difference of potential between M and O on the potentiometer circuit is not exactly equal to that existing between the same points, in other words the ends of the circuit including the galvanometer and the thermo-couple. For carrying out the measurement, this very condition must be obtained, and this is done by moving the slide G on the potentiometer circuit. As the latter is calibrated, it indicates directly the value of the electromotive force developed by the couple and therefore the corresponding temperature.

These movements take place automatically in the recorders (fig. 14); the values are expressed in degrees centigrade to two scales : 0 to 500° C. and 0 to 250° C and ferro-constantan thermo-electric couples are provided for checking them.

In the indicator instrument (fig. 15) the opposing current is balanced by hand, and the value is read off in millivolts, so that thermo-electric couples of any type can be used, provided use is made of the special tables for converting the readings into degrees; it can be used up to 1 600° C. A multiple position switch is provided to enable the potentiometer to be inserted in a number of different pyrometric circuits in rapid succession.

Although the indicating instrument is preferred for easily understood reasons, the accuracy and sensitivity are very good in both types, and this is also true as regards their sensitivity under the disturbances set up at high speed.

The indicated work done by the steam in the cylinders is usually recorded by Lehman electrical remote controlled

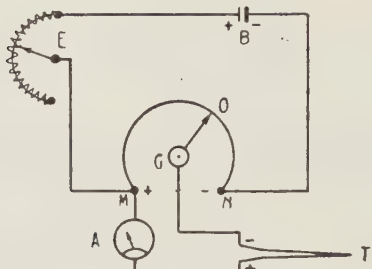


Fig. 13. — Diagram and potentiometric circuit of the Leeds & Northrup pyrometers.

indicators, for pressures up to 20 kgr./cm² (284 lb. per sq. in.). Maihak indicators are also available for pressures up to 80 kgr./cm² (1 140 lb. per sq. in.).

* * *

c) When testing electric locomotives, the dynamometer car is fitted up with the following measuring apparatus :

— a D. C. indicating-recording voltmeter, for 0 to 4 000 volts;

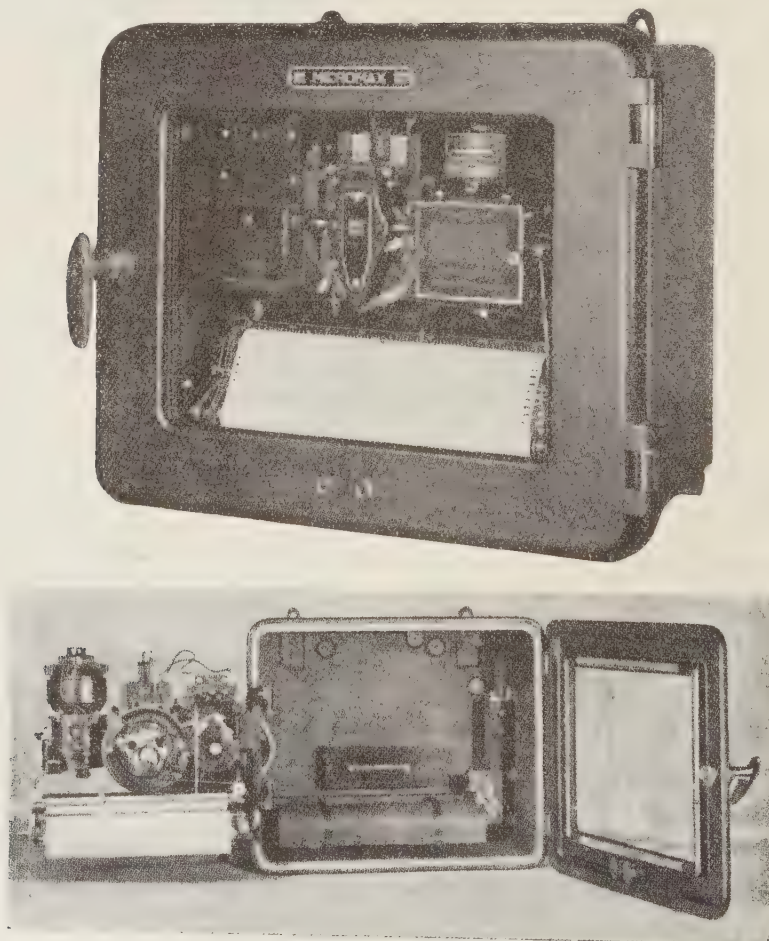


Fig. 14. — Leeds & Northrup recording potentiometers.

— an indicating-recording ammeter with separate shunt for 500 and 100 amperes to be fitted in the high-tension compartment of the locomotive under test;

— an indicating-recording wattmeter to be connected to these shunts, and additional separate resistances to measure 500-0-1 000 kw. and 750-0-1 500 kw. respectively, for the energy used or regenerated, with intermediate zero line;

— two D. C. meters, one for the energy consumed, and the other for that regenerated, each fitted with a counter reading a minimum of 10 kWh.;

— a meter for the auxiliary services circuit, with shunt for 15 amperes and additional resistances for 4 000 volts, reading a minimum of 5 kWh.;

— a portable precision ammeter, and a portable precision voltmeter, for testing and checking the above instruments.

The recorders cover the field to be recorded either automatically on a time

basis, or relatively to each recording scale of the dynamometer, so as to synchronise the recording of the electrical and mechanical measurements.

Each apparatus is provided with electro-magnetically controlled pens for recording either distance or time, as well as for making any reference marks desired by the operator. Each of these records corresponds exactly to those made on the dynamometer record.

The above instruments are protected, as they might be subjected to high-voltage currents.

Another instrument forming part of the group for electrical measurements, and much used for collecting mechanical data, is the oscillograph. This apparatus being well known need not be described here. The one used is of the Siemens type with eight elements (the two supplementary elements have been fitted on the side), with high sensitivity, a proper frequency of about 2 000 periods, interior resistance 4 ohms, maximum load 0.004 amperes direct current, and current constant about 0.075×10^{-3} amperes.

The light source is either an arc lamp (for making very fast photographic records) or an incandescent lamp.

The sensitive paper moves at a speed varying from 0.02 to 10 m. ($3/4''$ to $32'9''$) per second; the time is marked by a blade vibrating at $1/50$ th of a second.

For studying mechanical phenomena such as : relative displacements, accelerations, etc., primary elements with electrical resistance varying in terms of the displacement, or of the carbon type with resistance depending upon pressure, are used.

To measure the accelerations either in the vertical plane or in the horizontal, recorded by means of the oscillograph, piezo-electric quartz apparatus are also used, based on the characteristics of this mineral to produce electrical discharges when compressed on two opposed faces at right angles to the optical axis. The

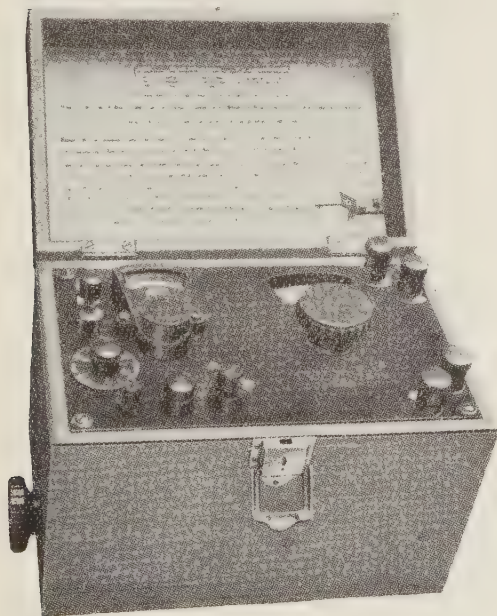


Fig. 15. — Leeds & Northrup recording potentiometer.

electric currents produced are very small, but are amplified in two stages to make them suitable for the oscillograph.

The variable pressures on the quartz are obtained by means of a metal weight of 3.5 kgr. (7.7 lb.) held in place by a metallic diaphragm, also passing through the centre of gravity, so that the apparatus is only sensitive to accelerations in the direction of its axis.

A filter cuts out vibrations above 20 per second from the oscillograph so as not to spoil the diagram by records which may be considered as parasitic.

Other similar apparatus is used to measure variable horizontal and vertical forces by applying the quartz to the two sides between which the force is exerted. The maximum allowable value is 15 000 kgr. (33 000 lb.).

The piezo-electric quartz instruments have been supplied by Messrs. Beaudouin, of Paris.

Using the oscillograph in railway work, especially on high-speed trains, for studying the working of the main parts, is a laborious task, but the results are very satisfactory.

The dynamometer car also includes an S.A.F.A.R. telephone equipment with three instruments; the centre one has a loud speaker, and the two at the ends, for the test locomotive and brake locomotive, are fitted with special receivers to ensure clear communications in spite of the noise.

* * *

The *Czechoslovak State Rys.* put into service, in 1925, a dynamometer car constructed by Messrs. Ringhoffer (Prague), fitted with Amsler equipment similar to that supplied to the Swiss Federal and French Railways.

This carriage is fitted with the following additional equipment :

— Maihak electric remote control indicators with Böttcher calculator, giving the indicated efficiency;

— electric indicating and recording thermometers for measurements in connection with the combustion gases, steam and feed water;

— Combustion gases ($\text{CO} + \text{H}_2$ and CO_2) analysers.

The *Jugoslav State Rys.* have a carriage fitted with a hydraulic dynamometer for measuring tractive efforts up to 25 000 kgr. (55 100 lb.), equipped with speed recorders, pressure gauges, pyrometers, and pressure indicators. In addition it is equipped with a Siemens combustion gas analyser and a Richard apparatus for brake tests.

The *Rumanian State Rys.* have had in service, since 1933, a dynamometer car made by modifying a bogie carriage built in 1928 by the Breda Works of Milan.

The dynamometer, which is able to record pulls of 30 000 kgr. (66 100 lb.), is of the hydraulic type with recording piston fitted with a standard helicoidal calibrated spring (Turton Bros.), with a maximum travel of 300 mm. (11 13/16"). Seeing that the helicoidal spring does not give deflections rigorously proportional to the tractive effort over the whole of the theoretical possible scale, this dynamometer can only be used satisfactorily for pulls between 0 and 22 500 kgr. (45 600 lb.).

The experimental equipment, in addition to the ordinary auxiliaries of the dynamometer : speed recorders, power integrators, etc., also include the following instruments :

— Maihak electric remote control indicators;

— Wegener & Mach (Quedlinburg) indicating and recording thermometers for the steam, combustion gases, etc.;

— vacuumeters for measuring the vacuum in the smokebox, firebox, and ash pan;

— gauges for measuring the exhaust pressures and back pressures;

— device for collecting samples of combustion gases for analysis by the Orsat method.

As regards the dynamometer, the allowable error is $\pm 1.5\%$ for pulls between 500 and 22 500 kgr.; as regards the travel of the paper the tolerance is also $\pm 1.5\%$ owing to the wear of the tyres.

* * *

CHAPTER II.

Measuring instruments other than those in the dynamometer cars.

Besides the test instruments mentioned above, there are many others available, which are not usually fitted in the dynamometer car, such as : a group of recording pressure gauges and other instruments specifically used for brake tests, which are normally mounted in a carriage; a Hallade recorder, sometimes used to note the behaviour of the running gear of the locomotive, relatively to the track conditions; many pyrometers, each fitted with a recorder, or indicator, arranged for indicating or recording at a distance, of the thermo-electric, platinum resistance, or mercury vapour couple type; a recording diaphragm vacuumeter; anemometers; second counters, etc.

* * *

CHAPTER III.

Brake locomotives for constant-speed tests.

Until 1928, the *Italian State Rys.* car-

ried out their dynamometer car trials with ordinary trains. In this way very useful results were obtained, which were confirmed in ordinary working.

Such a system, however, had many inherent drawbacks such as upsetting the running of the ordinary trains; delays and consequently faster running to make up the lost time, variations in the weight and composition, and consequently in the overall and unit tractive effort required, etc. These conditions, although they did not affect the accuracy of the experimental results required a large number of trial runs to be made so as to get a large enough number of figures free from irregularities, comparable with one another.

To overcome these drawbacks, as well as to enlarge the experimental field, this system was given up and since 1928 almost all tests have been carried out by using the brake locomotive. In the case of certain operating questions or when very high speeds are involved, the load is still made up of coaches, to form empty trains of constant composition running to a special timetable, and not subject to the difficulties mentioned above.

For constant-speed tests the Italian State Rys. use two brake locomotives, both on the Riggensbach system.

Two of the less important types of engines were used in this connection : one of the 675 group (former German P8 obtained as war reparations), and the other of the 670 group, a relatively old type, both being 4-6-0 engines.

The other characteristics of these locomotives are as follows :

	675 type.	670 type.
Total weight in working order	120 tons.	100 tons
Adhesive weight	51 tons.	45 tons.
Diameter of coupled wheels	1 750 mm. (5' 9")	1 920 mm. (6' 3 19/32")
Maximum hourly speed	100 km. (62 miles)	110 (68.3 miles)
Engine	2 cyl., simple exp.	4 cyl. double exp.
Diameter of cylinders	580 mm. (22 13/16")	HP. 370 mm. (14 9/16") LP. 580 mm. (22 13/16")
Piston stroke	630 mm. (24 3/4")	650 (25 5/8")

Boiler pressure	$\left\{ \begin{array}{ll} 12 \text{ kgr./cm}^2 & 14 \text{ kgr./cm}^2 \\ (170 \text{ lb./sq. in.}) & (199 \text{ lb./sq. in.}) \\ (\text{superheated steam}) & (\text{saturated steam}) \end{array} \right.$
Adhesive weight F_A , adhesion factor $1/7$	$\left\{ \begin{array}{ll} 7\,200 \text{ kgr. (15\,870 lb.)} & 6\,340 \text{ kgr. (13\,960 lb.)} \end{array} \right.$
Tractive effort F (based on the dimensions of the engine)	$\left\{ \begin{array}{ll} 10\,000 \text{ kgr. (22\,040 lb.)} & 8\,000 \text{ kgr. (17\,640 lb.)} \end{array} \right.$
Ratio $\frac{F_M}{F_A} =$	$\left\{ \begin{array}{ll} 1.38 & 1.26 \end{array} \right.$
Boiler feed	$\left\{ \begin{array}{ll} 1 \text{ standard injector.} & \\ 1 \text{ Knorr feed water heater.} & 2 \text{ standard injectors.} \end{array} \right.$

For simplicity as regards construction and working, instead of providing means for connecting the exhaust either with the smoke box (the normal arrangement) or directly with the atmosphere, as desired, the latter system has been adopted permanently by extending the blast pipe through the smoke box, immediately in front of the chimney. The blower, however, has been retained and enlarged to suit the two boilers, and during the trials a maximum smoke box vacuum of about 40 mm. (1 9/16") of water has been obtained in both cases.

This simple solution has shown, during eight years of trials with brake locomotives, that it not only produces sufficient steam for the normal requirements of the test, but also prevents, in the event of the locomotive under test failing on a rising gradient, the normal train service from being interfered with.

On the 675 type locomotive the exhaust of the compressed fluid is regulated by means of cone-seated valves, which can be operated separately from the cab, and are fitted on two pipes, each taken directly from one of the piston valves to the original position of the air admission valve, in connection with the admission chamber.

The adaptation of the 670 type locomotive was much more difficult as it is a non-symmetrical compound engine, and also there was some doubt as to the possibility of distributing the work equally between the high and low-pressure cy-

linders. In view of this, of the two discharge valves mentioned above, one was connected to the admission pipe and the other to the receiver; in addition a fan-shaped valve was fitted to the pipe through which the atmospheric air is drawn in. All these valves can be quickly operated from the cab.

As a result, the four-cylinder compound engine can be considered as divided into two practically independent parts, each consisting of a pair of cylinders of different diameters and consequently working with proportionally different pressures.

The load on the four connecting rods can be divided satisfactorily by a skilled driver who has only to keep an eye on the pressure gauges on the admission pipes and the receiver. No difficulty has been experienced in practice, nor any special difficulty in adjusting the resisting force.

The temperature of the compressed fluid is maintained between allowable limits by two small jets of water taken from the boiler, and discharging into the exhaust chamber of one of the piston valves; the water is evaporated and drawn into the cylinders.

In the case of the 675 type locomotive, the temperature of the compressed fluid measured on leaving the piston valves, even when developing a great resisting effort for a long period, does not exceed 300° C. (572° F.); in exceptional cases, when at high speed the whole possible

compression capacity has to be made use of, the temperature reaches some 320°C . (608°F .).

In the case of the 670 type locomotive, working in stages, the temperatures are always much lower.

Owing to the fluid in question being almost entirely air and at high temperature, the possibility of the oil in the cylinder valves carbonising must have attention. The lubrication by oil mixed with steam is even more necessary than on ordinary locomotives; for this purpose Michalk automatic pump lubricators with emulsifiers are fitted.

The indicated value of the maximum resisting effort varies with the speed as can be seen in the diagram, figure 16,

showing tests results with locomotive 675, such tests having been carried out with packings maintained under normal conditions, the amount of cooling water introduced in the piston valves being reduced when the speed fell. The particular form of the curve can be attributed to leaks of the fluid and to the heat transfer through the walls increasing with the time required to develop the thermodynamic cycle.

If the compression is total and the running speed exceeds 80 km. (50 miles) an hour, the pressure of the compressed fluid tends to become higher than that of the boiler (fig. 17), and for still higher speeds, is definitely higher, so that the resistance of the compression cycle is higher than the power developed when running as a counter-pressure engine.

This phenomenon is clearly shown in the diagram, figure 18.

Under these limiting working conditions, the locking device on the regulator has to be used to prevent it opening suddenly. A certain quantity of compressed air succeeds nonetheless in entering into the boiler, though not very much, it is true, and it can easily be got rid of by the blower; no drawback results therefrom as regards feeding the boiler, since in this case a Knorr feed water heater is used exclusively. As the latter cannot work on exhaust steam, a live steam connection is provided.

The average maximum resistance at the wheel tread for a complete revolution of a wheel is, for the type 675 brake locomotive, running at a speed of 80 to 85 km. (50 to 52.8 miles) an hour, some 5 000 kgr. (11 020 lb.), equivalent to 1 500 — 1 600 H. P. The adhesion, with a factor of 1/7, which is desirable if high powers have to be maintained over long distances under possibly varying atmospheric conditions, is 7 300 kgr. (16 090 lb.).

The difference between the two values is large, but the apparently large margin disappears when the polar diagram of the tangential forces is taken into ac-

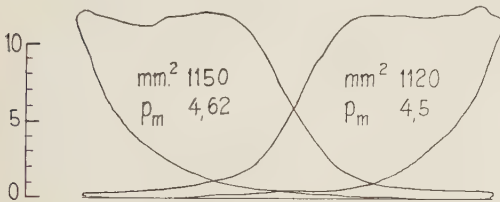


Fig. 16.

Indicated horse-power : 1 330.
Cut-off = 70 %.
Speed $V = 80$ km./h.
Back steam pressure working.

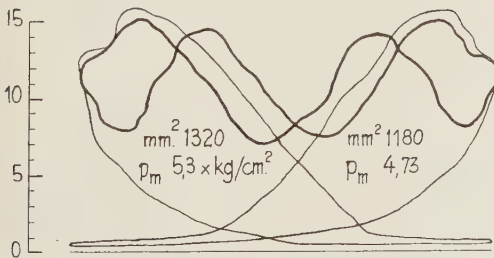


Fig. 17.

Indicated horse-power : 1 460.
Cut-off = 70 %.
Speed $V = 80$ km./h.
Full air compression.

Fig. 16 and 17. — Indicator diagrams taken of the brake locomotive when running as a back steam pressure engine, and as an air compressor.

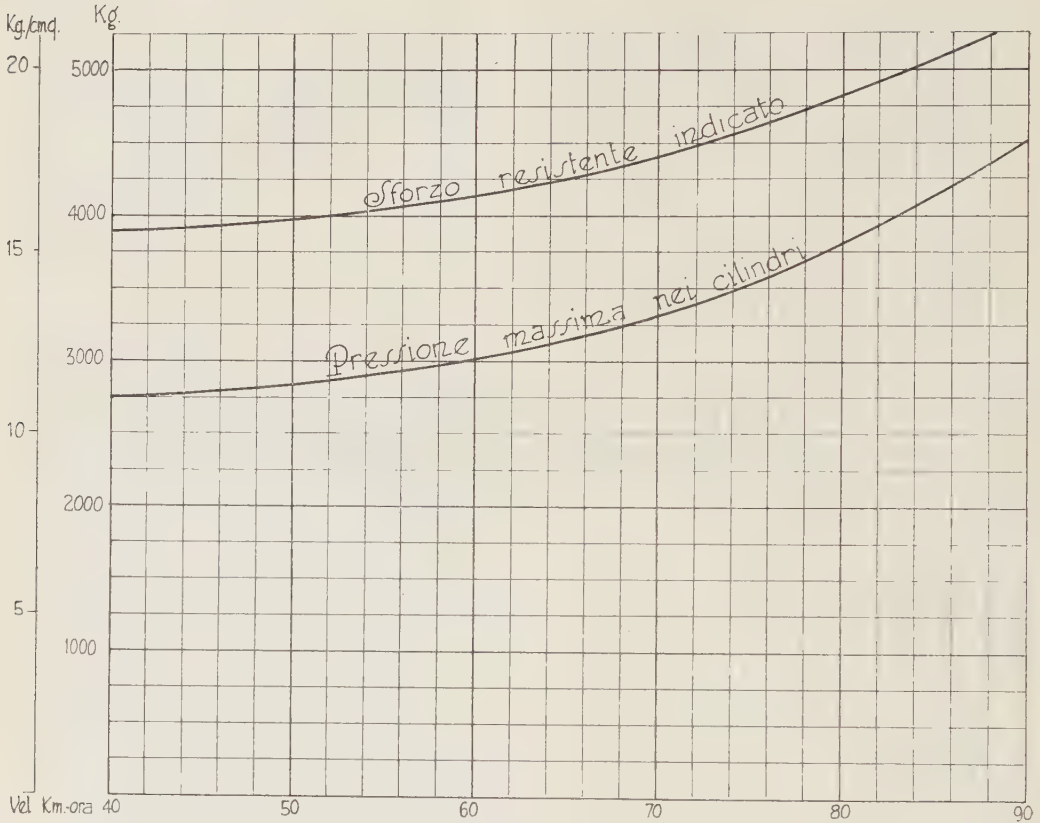


Fig. 18. — 675 type locomotive. Indicated resistance and maximum cylinder pressure curves in terms of the speed.

Note: Sforzo resistente indicato = indicated resistance. — Pressione massima nei cilindri = maximum cylinder pressure.

count. For certain positions of the cranks, the corresponding pressure of the fluid is such that, even allowing for the inertia of the rotating and reciprocating masses, the possibility of the wheels stalling is not negligible. In fact this would occur frequently when working at full compression at a speed above

80 km. (50 miles) an hour, if sand were not used freely.

In the case of the 670 type locomotive, the curve of the maximum resistance in terms of the speed differs from that of the preceding engine, as it was originally a compound engine and develops a resistance equal to the maximum adhe-

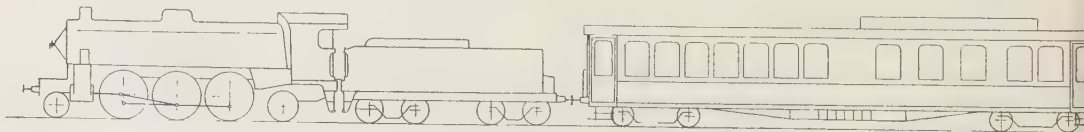


Fig. 19. — Diagram of the t

sion, even at relatively low speeds such as 50 km. (31 miles) an hour.

Such a brake locomotive has a high efficiency at all speeds between 50 and 100 km. (31 and 62 miles) an hour, provided that the resistance required, especially in conjunction with the greatest powers, is not close to the possible maximum, or that at least the working under these conditions is not maintained too long. This is due to the fact that this is an old type of locomotive with relatively light motion.

The 675 type locomotive is much more substantially built; this locomotive is used more frequently for constant-speed trials at speeds between 70 and 90 km. (43.5 and 56 miles) an hour, i.e. the most interesting speeds from the experimental point of view. The pull that could be recorded on the dynamometer with this type of engine at 80 to 90 km. (50 to 56 miles) an hour would be about 6 000 kgr. (13 220 lb.) on the level.

In Italy, however, there is no really flat line available, meeting all the other conditions for carrying out trials under constant power; in particular there is not sufficient length, which for certain classes of tests is an important factor. On the lines usually selected there are always gradients between 1 in 200 and 1 in 156.

On such gradients the effect of gravity on the whole test train reduces the allowable resisting force by some 1 500 kgr. (3 300 lb.) and the result is that at speeds of 80 km. (50 miles) an hour the locomotive being tested has to develop on the level less than 1 300 draw-bar H. P. in order to be able to maintain constant speed over all the sections of the line.

If this figure has to be exceeded, two

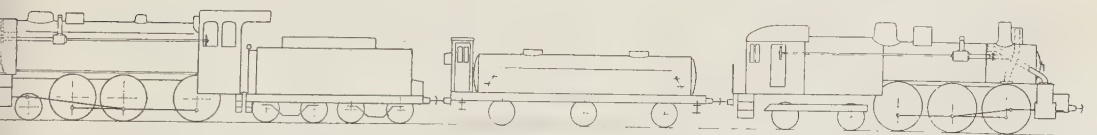
locomotives working in compression, as shown in figure 19, are used.

The constancy of the speed within ± 2 km. (1.2 miles) an hour relatively to the value selected for the test, is obtained easily enough at average and high speeds, by the use of either one or two brake locomotives. In the latter case the rear engine is used with the valves open and consequently with reduced resistance except on the down gradients, and the other ordinarily meets the variations in power to keep the speed constant.

This regulating action is obtained by keeping the cut-off in back gear at a high value (70 %) and by opening the valves releasing the compressed fluid. The resistance can be made to vary with the cut-off, but it was thought desirable to keep it at a high percentage as thereby the resistance during each wheel revolution is more uniform and the working of the dynamometer is not effected by certain oscillatory phenomena which might occur under certain conditions.

The most difficult condition arises when carrying out tests of low-power locomotives at speeds above 50 km. (31 miles) an hour, i.e. when the available force at the tender drawbar is only a little greater than that absorbed on the level by the dynamometer car and the brake locomotive with the valves open. In this case the field of regulation by compression is very limited, and owing to the gradient section of the line, the influence of which is particularly felt, the brake locomotive has to be put in fore gear and used to develop power to reduce the power absorbed by the train hauled.

Operating in this way complicates the driving; it is successful, however, provided, the driver acts in time, i.e. early



formation for high-power trials.

enough and carefully, in order to avoid any possibility of reversing the forces in play, or sudden changes.

When testing low-power engines at speeds not exceeding 50 km. an hour, sometimes one or two type 980 locomotives, in normal service on rack lines and consequently already fitted with the Rigenbach brake, are used.

The Italian State Rys., owing to the configuration of the country, group their locomotives into three classes as regards driving-wheel diameters : 1 850 mm. (6' 13/16") for passenger trains; 1 370 mm. (4'6") for goods trains, and 1 630 mm. (5'4 1/4") for mixed traffic.

So that the experimental results may be more easily applied to ordinary working, and taking into account what was said above, the dynamometer trials are generally carried out at three distinct speeds : 80, 50 and 70 km. (50, 31 and 43.5 miles) an hour, each corresponding to the cases mentioned above, so that the angular speed remains very close to an average common value.

The thermodynamic results are more easily compared in this way.

The highest test speed under constant working conditions is therefore 80 km. (50 miles) an hour, and the highest

power developed continuously at the drawbar has been 1 500 H. P. with two brake locomotives.

For a single type of locomotive (type 691) with 2 003 mm. (6' 6 7/8") coupled wheels, the test speed selected is 90 km. (56 miles) an hour, with an average draw-bar H. P. of 1 600.

The maintenance of the brake locomotives has not been particularly costly ; taken all in all per kilometer run, it is rather less than that of an ordinary locomotive seeing that the boiler, usually the most expensive part to maintain, runs long periods without requiring repairs.

On the other hand, the piston valve rings have to be changed much more frequently, about every 30 000 km. (18 600 miles), i.e. twice as often as on ordinary engines, except in the case of the low-pressure engine of the 670 type locomotive, where the life reaches 40 000 km. (25 000 miles).

The valves and pistons have to be well lubricated; the types 675 and 670 respectively use 10 and 12 grammes per km. (5.7 and 6.3 ounces per mile) of type B oil, the normal oil used on superheated locomotives, having the following properties :

Reaction by organic acidity	Neutral.
Density at 15° C.	0.911
Tar content	—
Flash point (PM)	300° C.
Cold test	Liquid at 15° C.
Saponifiable matter	None.
Products of distillation up to 310° C.	—
Engler viscosity at 50° C.	36
Engler viscosity at 75° C.	13.6
Engler viscosity at 100° C.	6.2

As regards the piston and piston valve packings, no particular difficulty has been experienced, except with those of the high-pressure cylinders of the 670 locomotives, which owing to the design have to be renewed frequently.

The regulating valves require practically no maintenance, whereas the other

parts of the brake locomotive have to be treated much the same as those of an ordinary locomotive.

The brake locomotives meet the experimental requirements very well, and whilst reliable results can be obtained very quickly, they also make it possible to occasionally study secondary pheno-

mena which are easily overlooked with other running test methods.

The clearness of the results and the time saving more than make up, as compared with the old method, the cost of fuel not used to work a paying load; the expenditure on staff owing to a more intensive use over a whole experimental cycle, is lower.

Several years of experience with brake locomotives have led us to think that when a railway wishes to use this test method, several locomotives must be equipped; unless the speeds and powers are to be restricted at least two fairly fast locomotives are needed, one of average weight and the other light, so that by using them separately or together, it is possible to obtain a large range of resistances.

If needed, in certain special cases a locomotive of the same type as that being tested can be converted into a brake locomotive. When it is realised that even a slight failure can upset the results, it is desirable as a rule, especially on long-distance tests, that the brake locomotive should develop much less resistance than its maximum, using if need be two brake units even when this is not strictly necessary.

As a result of following this practice, the number of spoilt test runs has been very small.

As regards the type of locomotive to be used as a brake locomotive, it is better to use very powerful heavy types, with a high ratio between the maximum calculated tractive power and the power at the maximum adhesion, and relatively low boiler pressure; in this way it is possible, by using the super-pressure of the compressed fluid, to correct the tendency of the resistance to fall off quickly at lower speeds. From this point of view compound locomotives are satisfactory when driven intelligently and carefully.

* * *

With the exception of the *Rumanian State Rys.*, none of the other Railways

covered by this report use brake locomotives.

The *Czechoslovak State Rys.*, however, are fitting up a few locomotives which will be used for dynamometer trials.

The *Rumanian State Rys.* have three class 230 (German P8 type) brake locomotives in service.

The alterations to these locomotives were the following :

— the blast pipe has been extended through the smoke box to the top of the chimney;

— the admission pipe has been provided with a branch pipe connected to a piston valve, directly operated by the driver to regulate the escape of the compressed air whilst the engine is compressing.

The maximum temperature reached by the fluid during a long period test is limited to 220° C. (428° F.) by injecting water from the boiler into the cylinders.

The cylinders and piston valves are lubricated by means of 50 % of ordinary mineral oil and 50 % of special super-heater oil.

The maximum resistance of each locomotive varies in terms of the speed between 1 000 and 3 500 kgr. (2 200 and 7 700 lb.). Generally when making tests, several brake locomotives are used as the draw-bar pull of a single engine at the maximum speed of 100 km. (62 miles) an hour is only about 1 500 kgr. (3 300 lb.).

The speed indicators are of the « Deuta » type and the actual variations of the effective speed relatively to the constant speed selected is within ± 5 km. (3.1 miles) an hour when running at 100 km. an hour, and ± 2 km. (1.2 miles) an hour for lower speeds of about 60 km. (37.3 miles) an hour.

* * *

CHAPTER IV.

Carrying out a complete test.

Whether the locomotive to be tested is a new one or one taken out of service,

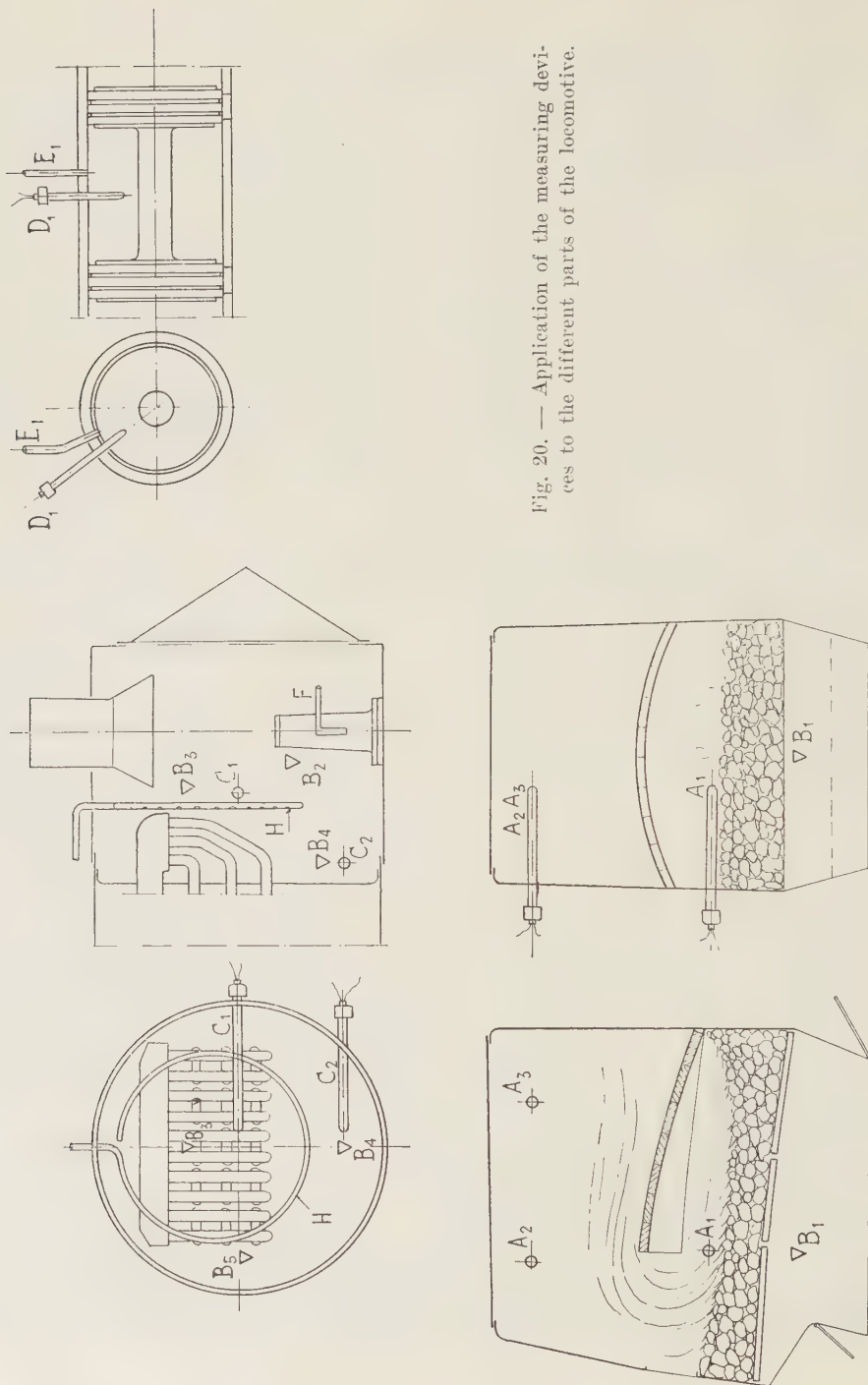


Fig. 20. — Application of the measuring devices to the different parts of the locomotive.

all the parts of the motion are systematically inspected, the valve gear is indicated the exhaust is lined up, and if need be the boiler and the wheels are examined.

Then the locomotive is handed over to the test staff and is used to work ordinary trains in order to get the rings properly bedded down and to make good any defects revealed during this period of running.

At the end of this period, which is usually short, the locomotive is equipped with various measuring apparatus, according to the object of the test to be made.

In the most usual case, i.e. for consumption tests, the following instruments are fitted according to the diagrams (fig. 20):

3 pyrometers ($A_1—A_2—A_3$) in the fire-box;

1 vacuumeter (B_1) in the ash pan under the grate;

1 or more vacuumeters ($B_2—B_3—B_4—B_5$) in the smoke box;

1 boiler pressure gauge;

1 pressure gauge (E_1) } in the admission
1 thermometer (D_1) } chamber
of a high-pressure
piston valve;

1 thermometer } on the receiver;
1 pressure gauge }

1 thermometer in the exhaust cavity of a piston valve;

1 pressure indicator on a high-pressure cylinder;

1 pressure indicator on a low-pressure cylinder;

1 thermometer on the tender;

1 thermometer } on the feed pipe

1 water meter } of an injector;

1 thermometer } on the feed pipe

1 thermometer } of the other injector

1 water meter } or of the feed water
heater;

1 collector (H) in the smoke box for the analysis of the combustion gases;

1 Pitot tube (F) in the blast pipe.

The following brief remarks on the

type and use of some of these instruments may be considered opportune.

The platinum-rhodium couple of the fire box pyrometers was formerly surrounded by a nickel sheath, but when laid directly on the layer of fuel after a certain time they began to fuse, owing to the nickel becoming covered with clinker, causing the fusion point to fall. The metal sheath has been replaced successfully on this pyrometer by a carbundum sheath, which however is fragile, and requires great care in removing the pyrometer from the firebox when refiring.

The pyrometers in the smoke box use an iron-constantan couple with a nickel or iron sheath.

All these pyrometers are connected by a compensated cable, either to the Siemens recorder, or to the multiple-diagram Leeds & Northrup recording potentiometers, in the dynamometer car.

The pressure gauges and thermometers are also connected electrically to the Siemens recorders in the dynamometer car, whereas the water-column type vacuumeters and the mercury-column back pressure gauges are simple indicators located in the locomotive cab.

As regards the recording water meters, their use has recently been given up — except in cases where it is desired to analyse the curves of the water fed to the boiler or when using exhaust steam injectors — principally because it is difficult to fit them and the same results can be obtained quite easily by measuring the volume of water in the tender and in the boiler after having calibrated them.

In order to obtain diagrams of the work done in the cylinders, the indicators used are fitted with electric remote control, so that there is no need to fit a shelter at the front end of the engine for the operators, which apart from saving time, prevents any changes in the air resistance conditions at high speeds.

When the trial runs are made at high

speeds, the indicator drum is driven by two wires in each direction, so as to prevent the diagram being deformed by the inertia of the drum itself.

In ordinary dynamometer car trials for ascertaining the characteristics of new or redesigned types of locomotives, large screened German coal mixed with about 25 % of Italian briquettes is used. When a strict comparison between the

results of the locomotives tested and those obtained with other types is not the object of the test, other types of coal such as Italian, Polish, English, Russian, etc., have been used — and in addition in a particularly interesting case semi-coke obtained by partial distillation of English coal.

The physico-chemical characteristics of the usual fuels used are the following:

	German coal. Large screened.	Italian coal. Briquettes.
Percentage of small	40	...
Upper calorific value, calories (B. T. U.) . .	8 300 (14 940)	7 995 (14 400)
Volatile matter, %	25.10	16.61
Fixed carbon, %	70.75	75.86
Ash, %	4.15	7.53
Sulphur, %	...	0.8
Mean breaking strength, kgr./cm ² (lb./sq. in.).	...	70 (995)

When carrying out consumption tests under constant working conditions, whether the engine is lighted up especially or is already under steam, twenty minutes before departure there is a partly burnt layer of coal over the grate, 10 to 15 cm. (4" to 6") thick (according to the working conditions to be maintained) and in the boiler the water is half way up the gauge, and the pressure about 8 kgr./cm² (114 lb. per sq. in.) At this moment the data relative to the initial conditions of the boiler and the tender are recorded and then the fire is made up so that at the moment of departure it is well alight and the pressure has risen to the blow-off pressure. At the end of the run care is taken to see that the level of the water is the same as at the beginning of the trial and that there is the same thickness of coal on the grate, making allowance for the ash collected during the journey. When the staff is properly trained, these results are easily obtained; the initial and final measurement of the layer of fuel is made by means of a bent iron rod fitted every 5 cm. (2") with teeth on the part stuck into the bed of fuel; in this way the estimate is not too much a matter of guesswork, and it is possible to correct

the results if the two measurements show there was a difference in the conditions. In the same way, as regards the water in the boiler, the initial and final quantities can be ascertained from tables of the volumes corresponding to different pressures.

The thickness of the bed of coal is kept as low as possible compatible with the working conditions to be maintained during the run; the firing is moreover controlled by the analyses of the combustion gases, the results of which are telephoned to the locomotive men from time to time.

The boiler is fed, whatever the system used, in such a way as not to alter the pressure by more than 3/10 of an atmosphere (4 lb. per sq. in.); in some cases, especially when ordinary injectors are used, the drop is 5/10 (7 lb. per sq. in.). Even if water meters are fitted on the injectors feed pipes, the water in the tender and the boiler is measured as well as overflow losses from the injectors, which latter, when of simple types, are 1 to 2 % of the total consumption according to the rate of firing.

When the feed apparatus are of different types, or when particular accuracy is required, the overflow water is

collected in a tank provided for the purpose, from which it is drawn into another larger tank in the dynamometer car.

The length of the trial run depends upon the object of the test and the type of locomotive to be tested. When the investigation is concerned not only with the consumption, but chiefly with the continuous maximum power the locomotive can develop, the test run is 160 or 215 km. (100 to 134 miles) long, according as the line selected is that from Rome to Chiusi or Bologna to Milan, in all cases without intermediate stops; these are for high-power locomotives hauling passenger trains, as in the case of goods trains or when the power is below 500 or 600 H. P., the run is reduced to 100 km. (62 miles).

Trials for specifically checking the consumption are made on longer runs, from 150 to 215 km. (93 to 134 miles) in the case of goods locomotives, and 215 to 315 km. (134 to 196 miles) for passenger locomotives. On the longer runs there is usually an intermediate stop to take water.

The lines over which these tests are usually run are double-track lines laid with heavy rails, so that ordinary trains are not interfered with by the trial runs.

The choice is guided, not only by general considerations, but also by the absence or limited number of speed restrictions. In the case of long distances, it is difficult to avoid speed restrictions completely, but when brake locomotives are used the effects are not serious if few in number; the only alteration in the working conditions is that the boiler does less work for short periods. Anyhow, in order to eliminate the effects from the final results the time run with regulator shut is reduced to a minimum and care is taken to regain as quickly and completely as possible the kinetic energy the train possessed before the speed reduction, by means of the brake locomotive.

At the beginning of the trial run, the

latter engine is used to get the train up to its normal speed — or a speed very close thereto — so that the trial locomotive works under the trial conditions as much of the time as possible.

The measuring appliances on the locomotive are mostly recorders and consequently do not require reading at intervals. In the case of the others, readings are taken according to the particular observations desired of any equipment, even when carrying out consumption trials.

As a rule three indicator diagrams are taken at intervals of 10 minutes and at the same time the values shown by the various non-recording instruments are noted, whereas the recorders are read at the end of the trial. Consequently at the end of the test a complete statement of the behaviour of the locomotive with the corresponding values of all the instruments at each period is available.

Sometimes readings are taken more frequently, but when making full-power tests with the cut-off and regulator opening remaining constant during the whole run this is usually unnecessary.

The measurements on which all the others are based are those relative to :

1. The water consumption;
2. The coal consumption;
3. The effective power.

The methods employed for ascertaining the first have already been indicated; in the case of the second, if the trial has been a regular one, and the conditions of the fire at the end of the test are comparable with those at the beginning, the difference in the weight of fuel on the tender gives the value required. The coal for the tests is kept under a shelter so as not to be exposed to rain, and carefully weighed before being loaded unto the tender. Seeing that the preliminary tests give sufficiently accurate indications of the fuel consumption, it is easy to make arrangements for the residual fuel at the end of the trial to be as small

as possible, and consequently any increase in humidity occurring during the run is negligible.

To calculate the power at the wheel tread (HP_e) the following formula is used :

$$HP_e = HP_g + \frac{V}{270} \left(Mr \pm Mh \right)$$

in which

HP_g = is the average power recorded at the dynamometer;

V = the average speed with regulator open, in km./h.;

M = the weight of the locomotive in metric tons, the average weight between the values at the beginning and end of the run;

r = the unit force, in kgr., absorbed by the locomotive when running, in-

cluding the air resistance at the average test speed;

h = the difference, in metres, between height above sea level at the beginning and end of the trial, only considering the part of the run made with the regulator open; the value Mh therefore will be positive or negative according to the profile of the line.

The value of the unit resistance r is deduced, in terms of the speed, for each type of locomotive, from curves in use for many years on the Italian State Rys.; however, an experimental programme is now under consideration for determining a new series of curves of greater accuracy over the whole range of speeds of practical interest.

Table A gives data relative to each run

TABLE A.

Test No.	of locomotive No.	Date
Test from	to	; km. : ; hours : ; minutes :
Average weight of the locomotive during the run :	tons	
Brake locomotive No.		
Object of the test		
Atmospheric conditions		
Type of coal used :	Briquettes :	kgr.; Small kgr.
Calorific value (lower) calories :		
Running time, seconds :		
Running with regulator open, seconds :		; km.
Corresponding average speed, km./h. :		
Work recorded by the dynamometer, kgrm. :		
Average pull in kgr.		
Average horse-power recorded by the dynamometer :	HP_g .	
Coal used (C) : {	Total kgr.	
	per m ² of grate per hour, kgr.	
Percentage of cinders in the smoke box relatively to the coal (C) used %		
Water fed into the boiler by the exhaust steam injector or feed water heater	} total kgr. per hour, kgr. temperature, degrees.	
Weight of exhaust steam recovered, per hour, kgr.		
Evaporation {		
{ Total		kgr.
{ Per hour		kgr.
{ Per m ² of grate and per hour		kgr.
{ Per m ² of direct heating surface per hour		kgr.
{ Per m ² of total heating surface		kgr.

and includes much information from which it is possible to get out, by ordinary methods of calculation, the various factors of interest in the dynamometer car trials, which are then entered on Table B.

Two of these factors, of the greatest importance, i.e. the power at the wheel tread and the indicated H.P. are effected by the semi-empirical character of the curves quoted above in the first case and in the other are based entirely on the indicator diagrams. As regards this latter equipment, of the classic type, and of great value when studying the details of the valve gear, etc., every reserve has to be made with regard to the accuracy of the results if used to measure the power, as the approximation obtained is generally insufficient and there is too much uncertainty in the corresponding value of the efficiencies.

When calculating the power at the wheel tread, the Italian State Rys. use, as already said, their own curves, and probably other railways do the same, although their curves or formulae may not be built up on the same bases.

A uniform method in this field would, therefore, be useful, especially when drawing curves of the resistance in terms of the speed, these curves varying from one railway to another, so far as they relate to different types of locomotives, but are all derived from identical experimental figures.

It would be necessary to agree a full experimental programme in all its details, as has already been done for the rail motor cars, in order to ascertain the various resistances of locomotives in service.

Dynamometer car trials on the *Rumanian State Rys.* are carried out in the following way :

The locomotive selected, which must be in good condition and have run from 5 000 to 10 000 km. (3 100 to 6 200 miles), is carefully inspected when leaving the shops, and the water in the boiler and the

tender are calibrated, suitable metric scales being used.

It is then fitted with Maihak pressure indicators, vacuometers, mercury pressure gauges, thermometers, pyrometers, etc., etc.

The types of fuel used are the following :

High grade « Valea Jiului » coal (from the Petrosan, Lupeni, etc., mines) with a normal evaporative coefficient of 6.3, used as washed coal containing 8 % of large;

Ordinary coal from the Comanesti, Codlea, Sorecani, etc., mines, with an evaporative coefficient of 4.7 to 5.2 used in the form of screened coal and briquettes (30 %);

Dehydrated lignite from the Schity, Golesti, Doicesti mines, with a an evaporative coefficient of 4.4 to 5;

Fuel oil from the Ploesti, Campina, etc., refineries with an evaporative coefficient of 8.5 to 9, a calorific value of 9 800 cal. (17 640 B. T. U.), an Engler viscosity of 17°, and a specific gravity of 0.87 to 0.97.

Either coal or oil can be burnt, together or separately, in the firebox of the most important types of Rumanian locomotives.

As a rule, oil is used before the trial begins, whilst keeping a sufficient layer of coal on the grate to prevent too much cold air getting in ; then 10 to 15 minutes before starting the coal is fired regularly from sacks containing 35 kgr. (77 lb.); and at the end of the trial care is taken to have nothing on the grate but clinker.

The section of line selected, 150 mm. (93 miles) long, is divided into 2 or 3 parts which are run over at different speeds so that each test lasts about an hour.

The fuel consumption is calculated by counting the number of empty sacks in the case of coal, or noting the levels in the tank when oil is used.

The same is done as regards the water, the longitudinal slope of the loco-

motive being taken into account. In order to calculate the total losses, each injector is fitted with a tank of 25 litres (5 1/2 Br. gall.) capacity, to collect the overflow water.

Supplementary measurements as regards the temperatures, vacua, back pressures, etc., are made every 5 minutes; in addition the time the boiler is fed with water and the time the regulator is open, as well as the length of the run between

the different stations, and the times of firing are recorded.

The samples of combustion gases collected during the trial are analysed at the end of the trial.

The heat balance-sheet of the boiler is drawn up on the lines of sheets C and D.

The production of steam in the boiler is estimated from the water taken from the tender, less the losses from the injectors when the latter are of the ordinary

TABLE C.

1. Type of locomotive.	
2. Date.	
3. Working speed (km./h.)	V.
4. Distance travelled (km.)	S.
5. Time taken for run (hours)	T.
6. Actual average speed (km./h.)	S/T.
7. Average boiler pressure (kgr./cm ²).	P _k .
7a. Average pressure at the piston valves	P _s .
8. Average superheat temperature (°C.)	t ⁰ _s .
9. Heat of the water at the average boiler pressure	q _k .
10. Total heat of the superheated steam corresponding to the mean temperature and pressure	λ _s .
11. Total heat of the saturated steam corresponding to the average boiler pressure.	λ _k .
12. λ _s — λ _k	
13. Exhaust steam pressure	P _e .
14. Exhaust steam temperature	t ⁰ _e .
15. Total heat of the exhaust steam	λ _e .
16. Temperature of the water in the tender and in the delivery pipe	t ⁰ τ ⁰ .
17. τ — t.	
18. λ _s — t.	
19. λ _s — τ.	
20. λ _k — τ.	
21. λ _e — t.	
22. λ _e — τ.	

TABLE C (continued).

23.	$\frac{\lambda_e - t}{\lambda_e - \tau} = a_1.$	
24.	$\frac{\lambda_k - \tau}{\lambda_e - \tau} = a_2.$	
25.	Tender water consumed	M.
26.	$Ma_1.$	
27.	Live steam used by the exhaust steam injector.	$0.03 M = \delta^m.$
28.	$\delta_m a_2.$	
29.	$Ma_1 - \delta_m. a_2 = M + d.$	
30.	Boiler water used	m.
31.	Saturated steam produced	$M + d. + m. = D_o.$
32.	Saturated steam used by the auxiliaries	$\Sigma \delta.$
33.	Superheater steam produced	$D_o - \Sigma \delta = D.$
34.	Water condensed from exhaust steam	$(M + d) - M = d.$
35.	Condensed water as a % of the exhaust steam	d/D.
36.	Superheated steam produced per km. run	$D/S = a.$
37.	Steam used in kgr./m ³ of cylinder volume	$a/A = q_0.$
38.	$(M + d) \tau = \pi.$	
39.	$m. q_k = \theta$	
40.	$\pi + \theta = \sigma.$	
41.	Saturated steam produced per hour	$D_o/T = D_k.$
42.	Saturated steam used per hour by the auxiliaries.	$\Sigma \delta/T.$
43.	Superheated steam used per hour	$D/T = D_m$
44.	$D_k \lambda_k.$	
45.	$\sigma/T = a.$	
46.	$D_k \lambda_k - a = C_k.$	
47.	$D_m (\lambda_s - \lambda_k) = C_s.$	
48.	$C_k + C_s = C_t.$	
49.	Normal steam produced	$C_t/639 = D_n.$
50.	Fuel oil used, in kgr.	C.
51.	Coal used, in kgr.	c.
52.	Calories in the fuel oil used	9500 C.
53.	Calories in the coal used.	3600 c.
54.	Total calories	$\Sigma Cc.$
55.	$\Sigma Cc + \frac{m.q_k}{\eta_k} = \Sigma Q.$	
56.	$\Sigma Q/9500 = B_o.$	
57.	Consumption of fuel oil, in kgr. per km. run	$B_o/S = b.$
58.	Consumption of fuel oil in kgr. per hour	$B_o/T = B.$

TABLE C (continued).

59. Quantity of fuel oil per m ² of grate area per hour	B/G = γ .
60. Calories in fuel burnt per hour	$\Sigma C_c/T = C_o$
61. Boiler efficiency	$C_t/C_o = \eta_K$.
62. Evaporative power expressed in kgr. of normal steam	$D_n/B = P_v$.
63. m. q_K/η_K .	
64. Quantity of superheated steam that would have been produced by the calories of the fuel burnt if the feed water temperature had been $\varphi^\circ\text{C}$	$\frac{C_t}{\lambda_s - \varphi} = D_e$.

TABLE D.

1. No. of test, date, fireman's name.	
2. Working speed	V.
3. Cut off	(ϵ)
4. Regulator opening relatively to the total area of the steam passages	
5. Air temperature	t° .
6. Weight of coal, in kgr. fired per m ² per hour.	
7. Source of supply of coal	
8. Calorific value of the coal	(K).
9. Coal burnt per hour	(B).
10. Temperature of the burnt gases	(T_c).
11. Boiler efficiency	(η)
12. Heat units unused	($1-\eta$) K.
13. Losses by radiation from the ash pan	$0.02 K = q_o$.
14. Other radiation losses	$0.05 K = q_s$.
15. Total radiation losses	$q_o + q_s = \Sigma q$.
16. Total losses relatively to the volume of burnt gases	CO_2 .
17. Total losses relatively to the volume of burnt gases	CO.
18. CO + CO ₂ .	
19. $\frac{\text{CO}}{\text{CO}_2 + \text{CO}} = \alpha_o$.	
20. Loss due to CO related to 1 kgr. of coal	$5680 \alpha_o = Q_1$.
21. $1.867 (\text{CO}_2 + \text{CO}) = \alpha_1$.	
22. $0.42 \text{ CO}_2 = \beta_1$.	
23. $0.3 (100 - \text{CO}_2) = \beta_2$.	
24. $\beta_1 + \beta_2 = \alpha_2$	
25. $\alpha_1 \times \alpha_2 = \beta$	
26. Loss due to burnt gases, related to 1 kgr. of coal	($T_c^\circ - t^\circ$) $\beta = Q_2$.

TABLE D (continued).

27. Hydrogen content of 1 kgr. of coal	H.
28. Water produced by the combustion of the hydrogen in 1 kgr. of coal	9 H.
29. Water in 1 kgr. of coal	H ₂ O.
30. Calories required to heat the water from the coal 1° C. . .	0.588 (9 H + H ₂ O) = δ
31. Total calories required to evaporate the water from the coal .	(Tc° - t°) δ = θ
32. Carbon in 1 kgr. of coal	C.
33. (Q ₁ + Q ₂) C = θ ₁ .	
34. Σq + θ + θ ₁ = Σ	
35. (1 - η) K - Σ = Φ	
36. 8100 - (Q ₁ + Q ₂) = ψ.	
37. Φ : ψ = X.	
38. Calories lost per kgr. of unburnt coal	8100 X = q ₁ .
39. Carbon burnt from kgr. of coal	C - X.
40. Loss due to CO per kgr. of coal	(C - X) Q ₁ = q ₁ .
41. Loss due to burnt gases	(C - X) Q ₂ = Δ.
42. Δ + θ.	
43. Percent loss due to radiation	q ₂ /K = η .
44. Loss due to unburnt coal	q ₁ /K = η ₁ .
45. Loss due to CO	q ₂ /K = η ₂ .
46. Loss due to the gases and vapours	q ₃ /K = η .
47. Loss due to radiation of ash pan	q ₄ /K = η ₄ .
48. η + η ₄ .	
49. η + η ₄ + η ₃ .	
50. η + η ₄ + η ₃ + η ₂ .	
51. η + η ₄ + η ₃ + η ₂ + η ₁ .	
52. η + η ₄ + η ₃ + η ₂ + η ₁ + η ₀ = 1.	
53.	

Excess air.

1. O ₂ .
2. N ₂ .
3. CO/.
4. O ₂ - CO/.
5. $\Upsilon = \frac{O_2 - CO/}{N_2}$.
6. Σ = 3.7619 Υ.
7. 1 - Σ
8. Excess air $\frac{1}{1 - \Sigma}$.

TABLE D (continued).

Train No.				Date		TEST No.					Section run over		
Working speed				km./h.		Cut-off (e)							
No.	Km.	Hour.	Level of hot water. h	Pressure.			Super-heat temperature. Ts	Vacuum.					
				Boiler. Pk	Valve. Ps	Blast pipe. Pb		Chimney. hk.	Smoke-box. hc	Firebox. hf			
1													
2													
3													
4													
5													
6													
7													
8													
9													
10													
11													
12													
13													
14													
15													
16													
17													
18													
19													
20													

Level of water in the tender.					Level of water on the locomotive.				
	Left side.	Right side.	Average.	Volume. m ³	Level measured.		Level at gauge.	Exact level.	Volume. m ³
					Front.	Rear.			
Start									
End									

Water used.			Correction $\pm$.		
Temperature of the water in the tender.	Coal used. Kgr.	Fuel oil used.		Time. Min.	Name of fireman.
		Level in the tender.	Kgr.		
Start					
End					
Average					

type, and adding when an exhaust steam injector is used the water recovered by condensation, calculated from the formula :

$$d.te + 0.03 M.rk = M (Tc - t),$$

in which

d = the quantity of the exhaust steam condensed;

te = the quantity of heat contained in one kgr. of exhaust steam;

Tc = the temperature of the water at the moment it is introduced into the boiler;

M = the quantity of water fed to the boiler, including that from the condensation of the exhaust steam;

$0.03 M$ = the quantity of live steam consumed by the injector;

rk = the total heat of one kgr. of saturated live steam;

t = temperature of the water in the tender.

The consumption of steam in the cylinders is calculated by reducing the quantity of saturated steam produced by the boiler by the quantity absorbed by the auxiliaries, the consumption of which is reduced to a minimum by using for the brakes compressed air produced by the pump of one of the brake locomotives, and doing away with the blower.

The steam required for heating the fuel oil, and for the fuel oil burner, when the boilers are oil fired, has been estimated as the result of tests as between 100 and 200 kgr. (220 and 440 lb.) and 300 to 400 kgr. (660 to 880 lb.) per hour respectively.

C. — Comparison between tests on a fixed test plant and tests on the line with brake locomotives.

In Italy there is no means of testing locomotives on a fixed test plant, so that there is no experience on this subject.

When the general layout of the various existing plants are considered, certain detail objections present themselves which suggest that running tests with brake locomotives may be better for some purposes.

On the test plant, the locomotive is not under the same working conditions as when in service on the line, and is not influenced by the surroundings in which it has to work : no parasitic stresses through imperfections in the track, no effects from the rail joints, no gyroscopic effects resulting from variations in superelevation, no transverse flexions, etc. All these causes may directly affect the working of the engine, when the way the motion and the frame are connected through the spring gear is taken into account.

Then too, in road tests the air has a direct and favourable influence on the combustion, seeing that it enters the ashpan with a certain dynamic pressure. On the other hand, the losses of heat from the boiler are increased. These conditions, unless fans are installed, cannot be reproduced on the fixed test plant. There are certain difficulties in getting the locomotive exactly vertically over the rollers, which if not done accurately introduces serious errors. It is true that this position is controlled by a suitable device, but it can change during the test, although slightly, without it always being possible to correct it or to take it into account.

The parasitic movements proper to the motion of the locomotive depend above all on the angular speed; not being damped out or lessened by the normal irregularities of the track — the wheels resting on the rollers of the test plant — these parasitic movements can give rise to resonance and set up considerable variations in wheel loads, and provoke slipping between the tyres and the rollers, that can only be prevented by altering the working conditions in order to eliminate resonance.

For all these reasons, the results obtained under constant working conditions on the test plant cannot be compared with those obtained in running tests. This system, however, is very useful as constant working conditions can be maintained and reliable comparisons be made between different series of tests.

For large railway systems, or for the common use of several railways, a test plant is a very useful method of obtaining reliable results quickly on most problems of interest, especially when completed by trials with a brake locomotive in the most interesting cases, with a view to arriving at the constants proper to the two test methods.

The method of carrying out tests with a brake locomotive gives results nearer those obtained in regular practice. But owing to possible irregularities in the running of the trains, temporary speed restrictions, variable climatic conditions, etc. this system is not always free from difficulties in observing the working conditions, especially on prolonged trials. Consequently it is as well to make a much larger number of tests than would be necessary with a fixed test plant. On the other hand, if the high cost of the building and operation of a test plant are taken into account, it will be seen that the brake locomotive method, which is sufficiently complete in itself, is the most convenient and consequently the better in many cases.

It can be admitted, in general, that all tests carried out by one method can be carried out equally well with the other, provided the difficulties encountered when carrying out the trials in each way, and the necessity of possessing data from previous tests showing the relation between the results of the two methods are taken into account.

Summary.

Since the Madrid Congress, there has been no clearly marked tendency in steam locomotives of new types. There has been a check, or rather an abandonment, of solutions based on the use of turbines and high-pressure boilers with a large water volume. On the other hand, a marked preference can be seen in most cases for locomotives of the normal type with relatively high pressure, but always within the range of medium pressure (25 to 30 kgr./cm²=356 to 426 lb. per sq.in.) with various detail improvements,

The locomotive of the classic type is therefore holding its predominating place in the railway world; however, certain manifestations are already observed, of a new tendency towards very-high-pressure boilers, with very high rates of evaporation, containing only a small quantity of water, using steam in a number of engines running at a high number of revolutions per minute.

On this side, there seem to be great expectations for the future of railway traction.

The importance of the advantages which might be obtained from this wide and attractive field, incites us to express the wish that investigations and experiments should be pursued actively.

As regards test methods, entirely satisfactory results can be obtained on the whole from fixed plants and by using brake locomotives.

It is nonetheless desirable that all the Railways should agree a complete experimental programme (as has been done for rail motor cars) well defined in all details; this will make it easier to compare the results of trials and also facilitate progress in this field.

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

13th SESSION (PARIS, 1937).

QUESTION IX.

Results obtained from the automatic and distant operation of signals and points, and from locomotive cab signals.

REPORT

(Austria, Czechoslovakia, Denmark, Finland, Germany, Hungary, Netherlands and Colonies, Norway, Poland, Sweden),

by A. MISZKE,

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The Questionnaire sent to the Railways of the Countries covered by our enquiry was divided into three groups of questions concerning :

- I. Automatic block ;
- II. Power-operated signal boxes;
- III. Locomotive cab signals.

* * *

CHAPTER I.

Automatic block.

QUESTION 1 referred to the *statistics of lines equipped with the various block signalling systems*. Table 1 below gives these statistics for the Railways which have supplied data in this connection.

Table 1 shows that automatic block

signalling is used much less than non-automatic block signalling. On the *Deutsche Reichsbahn* 0.07 % of the lines are equipped with automatic block signals and 48 % with non-automatic block; for the *Danish State Rys.* these figures are 0.7 % and 10 %, respectively; for the *Finnish State Rys.* they are 0.1 % and 100 %; for the *Netherlands Rys.* they are 2.6 % and 58 %; for the *Polish State Rys.* they are 0.3 % and 15 %; for the *Stockholm-Roslag Ry.* (Sweden) they are 2.5 % and 97.5 % (*).

(*) The *Czechoslovak State Rys.* do not use the automatic block system on their lines, owing (1) to their principle of using the absolute block system alone, and (2) to the large number of level crossings with barriers in most cases operated by the signalmen.

Of the lines equipped with automatic block signalling 39 % have mechanical (semaphore or disc) signals and 61 % day-light signals. The mechanical signals predominate on the *Netherlands Rys.*; the day-light signals prevail on the *Reichsbahn* and the *Danish State Rys.*, and are used exclusively in *Finland, Poland* and *Sweden (Stockholm-Roslag and Stockholm-Västeras-Bergslagen Rys.)*.

QUESTION 2. — *Types of signals used in automatic block signalling.*

For the day-light stop signal, in *Denmark, Finland* and *Poland* a red light — for the *danger* indication — and a green light — for the *line clear* indication — are used, superposed vertically. In *Germany* the stop signal has been combined with the distant signal as follows: two horizontal green lights on a level for the *line clear* indication; a green and a yellow light, the latter to the right of the first and also both on a level, for *proceed but stop at the next signal*; finally, two horizontal yellow lights on a level for *stop and proceed with caution*. At the entrance to stations and junctions a red light is used for *absolute stop*, possibly allowing a train to proceed only on receipt of special instructions, given in the case of interruptions in train operation. In *Poland* the disc signal used as a distant signal displays a yellow light when the stop signal is at *danger* and a green light when it is *off*.

The *Reichsbahn, Danish State Rys.*, and *Polish State Rys.* use, as a mechanical stop signal, a semaphore signal with horizontal arm or red light for *danger* and the arm raised at an angle of 45° or a green light for *line clear*.

As a mechanical distant signal the *Reichsbahn* uses a yellow disc with black

and white edge. The disc in vertical position or displaying two yellow lights inclined upwards from left to right shows that the signal is at *danger*; the same disc placed horizontally or displaying two green lights arranged as above shows that the stop signal is at *line clear*.

For the distant signal the *Danish State Rys.* add to the preceding stop signal a fish-tail semaphore arm with two winking lights: red for *stop* and green for *line clear*. On the *Netherlands Rys.* the distant signal is a semaphore signal with the arm inclined upwards for *line clear* and inclined downwards for *stop*, with green or yellow lights at night.

All Railways who have replied to our questionnaire use a single signal at junctions. The *Netherlands Rys.* use double-bracket semaphore signals at junctions. On the *Reichsbahn*, where day-light signalling is used, the stop signal and distant signal are always combined. The *Polish State Rys.* follow the same procedure, provided the signals are sufficiently close to each other. The *Netherlands Rys.* place in such cases the distant signal below the stop signal. The *Stockholm-Västeras-Bergslagen Ry.* uses in certain case three-position signals and the *Danish State Rys.* combine these signals simply by placing on top of the station home signal the distant signal showing the position of the station starting signal.

QUESTION 3 dealt with the average and maximum lengths of the block sections, with the moment at which the signals are put to *danger*, their normal position, etc., etc.

From the replies received it appears that the spacing of the signals and the length of the block sections depend upon the number of train movements and vary as follows:

—	Length of block sections.		
	Minimum.	Average.	Maximum.
<i>Danish State</i>	1.3 km.	...	2 km.
<i>Finnish State</i>	...	...	2.1 km.
<i>Netherlands Rys.</i>	3 km. 2 km.	...	6 km. 3 km.
<i>Polish State</i>	0.5 km.	...	2 km. (under consi- deration).
<i>Stockholm-Roslag Ry.</i>	...	0.640 km.	0.906 km.
<i>Stockholm-Västeras-Bergslagen Ry.</i> . . .	...	0.720 km.	1.1 km.

In *Germany* and *Holland* an overlap is used. The signal is put to stop by the first pair of wheels. In *Germany*, the preceding signal changes its aspect when the tail end of the train is at a distance from it equal to the braking distance. In *Holland* this distance is limited to 100 m. (109 yds.). In *Finland* and *Sweden* (*Stockholm-Roslag Ry.*) the signal is put to danger by the first pair of wheels. When the last pair of wheels pass it, the aspect of the preceding signal is changed. In *Poland* and *Sweden* (*Stockholm-Bergslagen Ry.*) the signal is put to danger when the first pair of wheels run over the block signal joint, and the preceding signal goes to *line clear* when the last pair of wheels pass over the same insulated joint. In *Poland* this insulated joint is situated at 200 m. (218 yds.) after the signal. In *Denmark* this takes place when the signal is being passed by the last pair of wheels.

In *Germany*, *Finland*, *Holland* and *Poland* the normal position of the signals is at *line clear*; in *Denmark* and *Sweden* (*Bergslagen Ry.*) it is partly the *line clear* and partly *danger*. On the *Stockholm-Roslag Ry.* the day-light signals are normally extinguished, so that this is the only railway which uses *approach lighting*.

Winking lights are used for distant signals in *Denmark* and *Sweden*.

Germany and *Poland* are the only countries in which the block signals carry a locking device for use by the linesmen.

QUESTION 4 referred to *trains stopped due to the block signal being at danger; the possibility of passing it in cases of steep gradients, heavy trains, any signal failure.*

The replies received show that on the *Reichsbahn* (two yellow lights) and on the *Finnish State Rys.* the block signal at danger compels the engine driver to stop and then to proceed with caution while in *Denmark*, *Holland*, *Poland* and *Sweden* it prescribes the absolute stop.

None of the Railways consulted allow this signal being passed when at stop, in the case of steep gradients or heavy trains. On the *Reichsbahn* the station home signal and the signal placed at junctions displays a red light for *danger*; these signals cannot be passed unless special permission has been received. On the *Danish*, *Netherlands* and *Polish Rys.* and partly on the *Stockholm-Bergslagen Ry.* the block signal at danger can be passed after receipt of authority by telephone from the nearest station. However, in *Poland* the train must under these circumstances proceed with caution. On the *Stockholm-Roslag Ry.* the

train can pass the automatic block signal at danger and proceed with caution if the train crew consider that it is only a question of a failure of the signal itself.

The answers to QUESTION 5 dealing with rules to be observed when *proceeding with caution* show that on all the Railways concerned the rules under which a train may proceed with caution are the same both by day and at night. The speed is limited to 20 km. (12 1/2 miles) per hour in *Germany*, and to 15 km. (9.3 miles) per hour in *Finland* and *Sweden* (*Stockholm-Roslag Ry*). In *Poland* the regulations prescribe certain speed restrictions. In *Finland*, in addition to the speed limits, the regulations compel the engine driver to regulate his speed so as to be able to stop in front of any possible obstacle. In *Germany* the driver may exceed the speed of 20 km. per hour and even attain the normal speed if visibility is good over two consecutive unoccupied block sections.

QUESTION 6 referred to *signals on block sections including a station, a junction or a long tunnel*.

On the Railways which have furnished data, the station home signal is also the block signal. It normally prescribes the absolute stop, and if it is at danger due to any failure it cannot be passed without special authority issued by the box (station). On the *Netherlands Rys.* in case of failure, the passing of such a signal at danger is allowed on receipt of authority from the signalman, who during the day displays a notice « Proceed » and at night a yellow light which he moves up and down. The driver must then proceed as far as the signal box and ask for instructions.

In the case of a section comprising a long tunnel with bad visibility (steam traction), the length of which considerably exceeds the average length of the block sections of the line and requires the installation of a block signal in the

tunnel itself, the Railways do not adopt signals differing from those ordinarily used as block signals, except on the *Polish State Rys.* where, in case of bad visibility, signals with much stronger lights are used. These signals are controlled and passed in the same conditions, and are repeated by audible signals.

QUESTION 7 referred to the *automatic block signals on tracks carrying traffic moving in both directions*.

No case of this nature has been brought to our notice by the Railways covered by this report.

QUESTION 8 dealt with the *protection of a train normally or accidentally stopped on any point of the section (normal stop in a station or accidental stop on open track)*.

The replies received show that all the Railways concerned consider that, under such conditions, the trains are sufficiently protected by the block signals. However, in *Denmark*, the train must be protected in addition by hand signals at a distance of 800 m. (875 yds.), when the signal remains at danger for more than ten minutes. The same rule applies in *Poland* where, however, the protection distance is in certain cases 900 m. (985 yds.) (for instance in case of an engine failure). In *Sweden* (*Stockholm-Roslag Ry.*) the protection by means of hand signals and detonators is compulsory where the stop is due to an accident.

QUESTION 9 concerned the *measures to be taken to meet a possible failure of a block relay remaining energized (duplication of relays)*.

In *Denmark* the block relays are duplicated on 5.5 km. (3 1/2 miles) of line. The other Railways do not take any measures of this nature; this applies also to old installations in *Germany* and *Poland*. In recent block system installations in *Germany*, an auxiliary relay is used in addition to the block relay, controlled

by the latter. The result obtained by this means is that a signal at stop cannot go to *line clear* without passing through the *caution* indication. If the train is not regularly protected the signal in the rear remains at *stop*, both in the old and new installations.

QUESTION 9b was worded as follows : *With mechanised signals do you take any measures to meet the case of a stop signal failing to give the stop indication. For instance, is it a rule that a block signal covering a block section, which has been cleared by a train, cannot resume the line clear position before the following block signal is effectively at danger? Do such provisions make the object of any particular regulations as to the action to be taken by a driver entering an occupied block (running at sight over two block sections)?*

On the *Reichsbahn* the same regulations are enforced for mechanical signals as for day-light signals, as stated under Question 3. On the lines equipped with mechanical signals the *stop* is absolute if the signal is at danger, i.e. if the arm is in the horizontal position or if a red light is displayed. Therefore even dead slow progress is prohibited where mechanical block signals are used.

On the *Danish State Railways* a block signal may not be put at *line clear* before the following block signal is at *danger*. The same rule is adopted in *Holland*, where however, the driver is allowed to proceed with caution over the next two sections.

On the *Stockholm-Västeras-Bergslagen Ry.* the station home signal must be at *stop* before the preceding signal can be set to *line clear*.

QUESTION 9c concerned the running of light-weight vehicles : railcars, steel or pneumatic-tired, trolleys, etc.

Do these vehicles cause the automatic block to function? Are there any special regulations for the running of these vehicles — addition of contact pieces, etc.

— *Or are there any particular regulations — block telephone?*

In *Germany*, only the ordinary rolling stock is admitted in automatic block territory. Among the other railways which have replied, the *Danish State*, *Netherlands* and *Polish State Rys.* are of the opinion that the light-weight vehicles must cause the automatic block installations to function while the *Finnish State Rys.* are of the contrary opinion as regards light railcars. On the *Danish State* and *Netherlands Rys.* the trolleys have insulated axles. The *Polish State Rys.* use the block telephone for trolleys running on lines equipped with automatic block signalling.

Finally, the *Stockholm-Västeras-Bergslagen Ry.* states that in its opinion trains only and not trolleys should affect the operation of the automatic block.

QUESTION 10 inquired *whether the use of certain electric braking devices (magnetic brakes, for instance) had any effect on the operation of the automatic block.*

The replies received show that the Railways covered by this report do not use such braking devices, except the *Deutsche Reichsbahn* and *Danish State Rys.*, who are of the opinion that electric brakes do not affect the operation of the automatic block.

Replying to QUESTION 11, the Railways concerned stated that they have no automatic block installations functioning otherwise than by means of track circuits, i.e. with treadles or wheel counters, etc.

QUESTION 12 related to *the statistics of failures in automatic block signalling installations, mechanical (semaphore) or day-light signals being dealt with separately, such statistics showing the number of failures per signal, per kilometre of track, etc., as well as the average number of trains stopped on account of one failure.* This question referred also to *fail-*

ures against safety, i.e. those failures with which a stop signal does not go to danger in spite of the block section being occupied.

The *Deutsche Reichsbahn* and *Finnish State Rys.* state that signal failures in automatic block signalling are very rare; in fact, the *Reichsbahn* does not consider it worth while to prepare special statistics. Neither these two Railways nor the *Netherlands Rys.* mention any failure against safety. The *Polish State Rys.* and the *Stockholm-Västerås-Bergslagen Ry.* have also replied negatively, which allows us to assume that on the above railways failures must be extremely rare, if they happen at all.

The only statistics of failures received — but not against safety — were from the *Netherlands Railways*, as follows :

In 1933, 0.14 per signal, 0.1 per km. of track;

In 1934, 0.27 per signal, 0.2 per km. of track;

In 1935, 0.2 per signal, 0.14 per km. of signal.

In all these cases the automatic or semi-automatic signal was at *stop* and could not indicate *line clear*.

This Railway points out that the figures for 1933 are more accurate, being the same as for 1928 to 1932. The figures for 1934 and 1935 were unfavourably affected by tests with resistances inserted in the circuits, in order to reduce current consumption.

The signal never remained at *line clear* while the block section was occupied. On the contrary, in certain cases a broken rail was revealed by the signal remaining at danger. This Railway is not in a position to give the average number of train stops caused by failures; it is therefore assumed that this number must have been insignificant.

In *Germany* no case has been reported of an automatic block signal giving the *line clear* indication in spite of the section being occupied. Nevertheless, to prevent a possible failure of this nature,

it is considered necessary to use relays as described in paragraph 9a.

QUESTION 13 was worded as follows :

Have you experienced any accidents or incidents due to the engine driver entering an occupied section and not proceeding with caution as prescribed in such a case? Do not such incidents reveal systematical errors of the engine drivers? In particular, are not engine drivers proceeding with caution in an occupied section inclined to resume normal speed after sighting the signal at the end of the section at clear, without duly considering the state of occupancy of the section as far as this signal?

The *Deutsche Reichsbahn*, *Finnish State Rys.* and *Netherlands Rys.* do not mention any case of this nature. The *Danish State*, *Polish State* and *Stockholm-Västerås-Bergslagen Rys.* supplied no information in this respect. The *Reichsbahn States* that engine drivers observe the existing rules conscientiously.

With regard to difficulties experienced due to the condition of the track under different climatic conditions (heavy rain, snow, low temperatures) and repairs to the track, the *Reichsbahn* has experienced no appreciable difficulty provided the track and insulated joints have been inspected periodically and kept in good condition.

On the *Netherlands Rys.*, after heavy rains certain anomalies were observed in the track relays of new installations before the resistances had been properly adjusted. In their opinion the electrician should inspect each section every two months.

The *Polish State Rys.* state that in cold weather the feed current to the insulated track sections should be reduced as the voltage increases enormously; in snowy or rainy weather the difficulties in feeding such track sections are not so great. Proper maintenance of rail joints is extremely important. Furthermore, rail creep endangers the insulated joints.

The *Stockholm-Roslag Ry.* states that a certain amount of trouble has been experienced in the insulation between block sections owing to large differences in length of the rails through expansion at high temperature during the day and contraction at low temperature during the night.

The other Railways do not mention any difficulties of this nature.

With regard to *essential modifications which should be introduced on electric traction lines*, the *Danish State Rys.*, *Polish State Rys.* and *Stockholm-Roslag Ry.* are of the opinion that impedance bonds should be used, which however, in the opinion of the *Polish State Rys.* tend to increase the maintenance costs and render track maintenance work more difficult.

* *

CHAPTER II.

Remote control of points and signals.

I. — Power-operated signal boxes.

Power operated signal boxes are those from which the points and signals are operated electrically, hydraulically, pneumatically, etc., at all events by means other than the signalman's muscular effort.

IN QUESTION 14 the Railways were asked to give the number of power boxes and their types : electric, hydraulic, hydro-electric, hydro-pneumatic, etc.; the number of signal boxes in relation to the length of line owned and to the total number of interlocking frames.

The replies sent by the various Railways are given in Table 2 below :

(The information received from the *Royal Hungarian State Rys.* in answer to this question was not sufficiently clear,

TABL

	<i>Deutsche Reichsbahn.</i>	<i>Danish State.</i>	<i>Finnish State.</i>	<i>Hungarian State.</i>
Power-operated signal boxes.				
Number of signal boxes :				
(a) electric	1 250	79	2	14
electro-pneumatic	50	...	...	...
(b) in relation to the total length of lines owned	$\frac{1\ 300}{53\ 000} = \frac{1}{41}$	$\frac{79}{2\ 510} = \frac{1}{32}$	...	$\frac{14}{7\ 640} = \frac{1}{546}$
(c) in relation to the total number of interlocking frames	$\frac{1\ 300}{17\ 800} = 7.3\%$	13 %	$\frac{10}{23} = 4.4\%$	$\frac{14}{986} = 1.4\%$
(*) There are in addition 5 mechanical signal boxes where only the signals are operated electrical				

so that the figures given in this table for the above Railways may possibly be not strictly accurate.)

QUESTION 15 asked to make a distinction between signal boxes with individual levers and those with route levers; to state the devices used in order to reduce the number of levers in the signal boxes, and to state which form of lever is considered more suitable.

The replies received show that all signal boxes mentioned in Table 2 are equipped with individual levers, i.e. there is one lever per point or signal or per group of apparatus controlled simultaneously from the box.

The Railways consulted do not have signal boxes with route levers, i.e. where a single lever operates all points and signals in a given route.

Only the *Polish State Rys.* are using an

arrangement to reduce the number of levers in the signal boxes. The *Stockholm-Västeras-Bergslagen Ry.* uses a similar arrangement in one of its signal boxes, and the *Danish State Rys.* use it for shunting signals.

With respect to the question as to which kind of lever is most suitable (ordinary levers, small hand-levers, push-buttons, etc.), opinions vary.

The *Reichsbahn* usually employs push-buttons, also small hand-levers in certain cases. Both types of lever are retained in their final position by means of a catch. They are covered with an enamel coating, the colour varying according to whether it is a point, signal or route lever.

The *Polish State Rys.* prefer the ordinary type of lever, while the *Netherlands Rys.* and the *Varberg-Boras-Herrljunga Ry.* (for their small stations) consider the push-button the most suitable type.

Netherlands Rys.	Polish State.	Sweden.					Czechoslovak State.
		Stockholm Västeras- Bergslagen. Ry.	Halmstad- Nässjö. Ry.	Stockholm- Roslagen. Ry.	Varberg- Boras- Herrljunga. Ry.	Helsingborg- Hässleholms. Ry.	
72	68	3 (*)	2	2	10	1	8
...	1	...	...	...	...	...	7
$\frac{72}{3400} = \frac{1}{47}$	$\frac{1}{264}$	$\frac{3}{479} = \frac{1}{160}$	...	$\frac{2}{280} = \frac{1}{140}$	$\frac{1}{12.7}$	$\frac{1}{118}$	$\frac{15}{3544} = \frac{1}{235}$
$\frac{72}{312} = 8\%$	4.3 %	$\frac{3}{70} = 4.3\%$	$\frac{2}{43} = 4.7\%$	...	$\frac{10}{23} = 4.4\%$	$\frac{1}{21} = 5\%$	$\frac{15}{2450} = 0.6\%$

The latter Railway uses hand-levers in large stations. Handlevers are preferred by the *Halmstad-Nässjö-Railway*.

The *Czechoslovak State Rys.* use push-button type levers in their electrically controlled boxes and ordinary levers in electro-pneumatic signal boxes.

QUESTION 16 was worded as follows :

(a) *How do you obtain, in your power boxes, the interlocking which is obtained mechanically in your ordinary manual signal boxes? (For instance, interlocking between two stop signals covering the same track section, which therefore should not be allowed to be set at line clear simultaneously).*

Do you obtain this interlocking :

I. *Mechanically, between levers ?*

II. *Electrically, by means of electric interlocking devices which lock the levers ?*

III. *Electrically, by means of relays cutting off the energy to the points or signals to be locked, without affecting the levers themselves, which remain always in the line clear position?*

Etc....

(b) *What steps do you take in case of failure ?*

Germany and Holland definitely prefer mechanical interlocking (I). The opinions of the other Railways are divided.

In *Germany*, the interlocking between the various levers (point levers, route levers, signal levers) is obtained mechanically, in a manner similar to that adopted for ordinary central plant. In addition, electric interlocking devices are used, which work in conjunction with the mechanical interlocking devices described above. Electric interlocking is obtained by means of contacts which are placed on the axis of the levers, by means of electro-magnetic locks, and finally by means of intermediate relays.

The *Danish State Rys.* and *Finnish State Rys.* have adopted the first two methods (I and II). The *Danish State* has in recent years preferred the second method for large stations.

The *Netherlands Rys.* prefer mechanical interlocking, as previously stated.

The *Polish State Rys.* use the Siemens & Halske system with mechanical interlocking between levers, and the Ericsson and Westinghouse systems with electric interlocking by means of electric lever locking devices.

The number of power-operated boxes owned by the following Swedish Railways is as shown hereafter :

1. *Stockholm-Roslag*, 2;
2. *Stockholm-Västeras-Bergslagen*, 3;
3. *Halmstad-Nässjö*, 2;
4. *Varberg-Boras-Herrljunga*, 10;
5. *Helsingborg-Hässelholms*, 1.

The interlocking systems used in their signal boxes are given in Table 3 :

TABLE 3.

Interlocking system.	Railways				
	1	2	3	4	5
I	1	...	2	2	...
II	...	1	...	...	...
III	1	2	...	8	1

The *Czechoslovak Rys.* do not mention how many signal boxes belong to each interlocking system, but they generally use electric and mechanical interlocking, Siemens & Halske (electric) system and the Westinghouse (electro-pneumatic) system power boxes. In addition, the point operating devices are arranged in such a manner that, when points are violently burst open trailing, the route signal being in the line clear position, this signal is automatically returned to danger.

The regulations concerning the measures to be taken in case of failure vary from one Railway to another.

On the *Danish State Rys.* the points which are out of order are locked by means of padlocks when a train is passing over them. Hand signals are used in this case on the *Finnish State Rys.* and the *Varberg-Boras-Herrljunga Ry.* (Sweden). The *Hungarian State Rys.* operate the points manually and the fixed signals are replaced by hand signals; on the *Netherlands Rys.* the trains are piloted.

On the *Polish State Rys.* in case of failure of the power control apparatus, points are worked by hand. If the signal is also out of order, hand signals are used.

The *Czechoslovak State Rys.* — though not replying strictly to our question — have supplied information which may be considered interesting. The following measures are taken particularly in cases of failures in the current feed line :

(1) In power operated signal boxes where accumulators are used, care is taken that the capacity is sufficient to feed the installation during 48 hours at least;

(2) Signals lighted electrically by current from the network are connected automatically to the stand-by supply which may be the accumulator battery, or to the reserve generator set;

(3) In electro-pneumatic signal boxes

a spare compressor reservoir is provided, and in addition, small reservoirs are provided for use at the points and signals, containing sufficient air for approximately 10 operations.

QUESTION 17 : a) *Information regarding the use of various safety devices, viz.:*

1. *Indication locking of a lever in connection with the actual operation of the signal or points operated i.e. a device for ensuring that a lever can only make its full movement if the point or signal operated by this lever has effectively completed its movement.*

Affirmative answers were received from :

— the *Deutsche Reichsbahn* (detailed below);

— the *Danish State Rys.*, with restrictions for certain types;

— the *Polish State Rys.*, with certain restrictions concerning electric interlocking apparatus;

— the *Stockholm-Västerås-Bergslagen Rys.*, with respect to one power-operated signal box;

— the *Helsingborg-Hässleholm Ry.*;

— the *Czechoslovak State Rys.*

On the *Deutsche Reichsbahn* a signal cannot be set at *line clear* unless the route in question has been properly set by operating the route lever and the latter has been electrically locked in its new position. By operating the route lever, all the points, protecting signals, etc., are interlocked mechanically in the desired position and the holding currents of conflicting signals interrupted by contacts placed on the axis of the route levers. At the same time a check is made by means of the holding current of each signal that the corresponding points are in the desired position (white disc), and that all the point control indications have been received (the coloured indication disc changes from red to white). Only when all these conditions are fulfilled can the electric lock of the route

lever be energized by means of the holding current of the signal and the lever be released to complete its stroke. After this operation, the route lever is electrically locked by the route interlocking electro-magnet, to prevent its movement in the opposite direction; the coloured disc of this electro-magnet then goes from red to white. As a general rule, the route levers are combined with the signal levers, thus forming the so-called « route signal levers »; no modification is entailed in the method of working.

II. *Indication locking of a signal lever in connection with the actual position of the points and signals concerned by the signal, whereby a signal cannot be put off unless the points and the corresponding protecting signals are actually in the correct position.*

Is this locking constant i.e. does the signal at line clear go back to danger automatically if the control of one apparatus (signal or switch) fails, or does it only last an instant while the signal is being operated to display the line clear indication?

All Railways use constant locking, with the exception of the *Stockholm-Roslag* and the *Halmstad-Nässjö Rys.* who have adopted instantaneous (temporary) locking.

The *Reichsbahn* has supplied the following detailed information :

The holding current of the signal operates the clutch connecting the signal arm to the motor. In consequence, it flows constantly even if the signal is in the clear position. If for any reason there should be a failure in the points, etc. (failure in the control device) while the signal lever is being operated or while the signal is in the *line clear* position, either in the area governed by the signal, or in the controlled section, the holding current of the signal is cut off and the signal is automatically put to danger.

For the electrically operated signals

the colour light signals and the mechanical signals with electrically operated arms, the *Czechoslovak Rys.* use an interlocking system in which the *line clear* signal is automatically placed in its normal position as soon as the entire train has passed the corresponding insulated rail, or as soon as through a trailing movement, the point is separated from the stock-rail, thus breaking the contacts on the point detector.

III. *Point locking, i. e. device to prevent the points from being moved while they are being passed over by a train.*

The *Hungarian* and *Polish State Rys.*, as well as all the *Swedish Railways* which have supplied information, state that such a device is used on their lines, without however giving any details. The *Finnish State Rys.* have adopted it in certain cases, and the *Netherlands Rys.* in very special cases only.

On the *Reichsbahn*, the operation of points during the passage of a train is prevented by the electric interlocking of the route, and this interlocking must be completed before it is possible to operate the signal lever.

On the *Czechoslovak State Rys.* all safety installations, of whatever type or control system, which are affected by a train movement, are arranged in such a manner that the points are mechanically and electrically interlocked and cannot be operated or released until the train has completed the route in question, or after the unexpected cancellation of the electric interlocking. This latter operation necessitates the breaking of the seal, which procedure must be entered in the register and reported to the maintenance and inspection staff. Once the train has completed the route, the points are released by the assistant station-master.

IV. *Section locking (arrangement by which a stop signal at the entrance of a track section cannot be cleared unless that section is actually free).*

In *Germany*, this arrangement is used

when the station tracks cannot be seen over their whole length, neither from the signal box nor from neighbouring boxes. If, however, the tracks can be seen, the *line clear* indication is given by block apparatus.

In *Finland* section locking is used in certain cases in connection with the automatic block and electric control apparatus.

In *Denmark*, *Holland* and *Poland* this route locking is obtained partially in certain cases. The *Helsingborg-Hässleholms Ry.* uses it in its only power-operated signal box. The *Varberg-Boras-Herrljunga Ry.* has not adopted route locking in any of its 10 power-operated signal boxes.

The other Railways have not supplied any information on this subject.

V. (1) *Route locking, or traffic locking (arrangement by which the danger indication of a stop signal in the rear of a train which has not yet completed the route in the signal box area will not allow another conflicting route to be set.*

(2) *Is this obtained in an absolute manner by means of track circuits or treadles, or is this route locking obtained in a less complete manner which, however, you consider sufficient in practice, by the use of a time release?*

(3) *In the first case, at which time do you allow another route to be set. Do you wait until the first route is completely freed, or do you use sectional release route locking?*

(4) *If you wait until the route is completely freed, do your operators have at their disposal a device of cancellation of the route locking for shunting movements.*

(1) Route locking has been adopted in a general manner by the *Reichsbahn*, the *Finnish* and the *Hungarian State Rys.*, the *Netherlands*, *Polish State* and *Swedish Rys.*, with the exception of the *Stockholm-Västerås-Bergslagen Ry.*, where it exists only in one of their signal boxes,

and by the *Danish State Rys.* where its use has been limited to a few stations.

The *Reichsbahn* states that unless it is automatically put to danger by the train passing over a length of insulated rail, the signal showing *line clear* is returned to danger when the train has reached a point where its tail lights can be clearly seen from the signal box. A route which is set for a given movement in the control area of a signal box, cannot be released until the train has passed all the points in that area which have been interlocked for the movement in question. As long as the route is not released, the interlocking prevents the setting of a conflicting route.

(2) Route locking is generally obtained on all Railways by means of insulated tracks. In addition to this procedure, the following are also used : in *Finland*, rail contacts; in *Hungary*, mercury or mechanical contacts; and on the *Stockholm-Roslag Ry.*, mercury contacts.

The *Reichsbahn* states that on their lines the cancellation of the route takes place either automatically by the passage of a train over a length of insulated rail, or manually (cancellation push-button), by a separate operator when absolutely sure that the route has been released. For the automatic cancellation of the route no devices or arrangements are used other than insulated rail lengths.

On the *Czechoslovak Rys.*, to make the operation of the safety devices dependent on the train movements, insulated rails with the necessary accessory apparatus are used. It is proposed to use time releases for the new rail current switches.

(3) Complete release of the route locking is used exclusively on the *Finnish*, *Hungarian* and *Polish State Rys.* and on the *Stockholm-Roslag*, *Halmstad-Nässjö* and *Varberg-Boras-Herrljunga Rys.* The *Danish State Rys.* use complete release route locking and sectional release route locking; this applies also to the *Deutsche Reichsbahn* in the case of large areas.

The *Netherlands Rys.* use complete route locking and in many cases sectional release route locking.

The *Helsingborg-Hässleholms* and *Stockholm-Västeras-Bergslagen Rys.* use exclusively sectional release route locking; on the latter Railway this is automatic.

The *Reichsbahn* states in this connection that if an area is very large and it is not possible to wait until the entire route has been released, as otherwise traffic would be unduly held up, partial releases are provided which allow other movements to take place on a portion of the route (shunting movements or setting of another route, etc.), as soon as the train has run over the locked points in that portion of the route. The release of sectional routes is always operated automatically by the train itself. A special route lever is provided for each sectional route.

(4) A route cancellation device for shunting movements is only used on the *Halmstad-Nässjö Ry*; on the *Varberg-Boras-Herrljunga Ry*. it can be used on the authority of a higher grade official.

VI. *Approach locking (device by which, after a route « A » has been set, a conflicting route « B » cannot be set — after the signals of route « A » have returned to danger — unless the signalman is absolutely positive that the train expected on route « A » will have sighted the distant signal at danger).*

Is this obtained in an absolute manner by the use, for instance, of insulated tracks, or is this approach locking obtained in a less complete manner, which, however, you consider sufficient in practice, by the use of a time release ?

The replies received show that such a device exists in the semi-automatic electric installations of the *Reichsbahn*; it is employed in an almost absolute manner in a number of installations of the *Polish State Rys.* The *Stockholm-Roslag Ry.* has also adopted this device by using

insulated tracks with or without mercury contacts.

QUESTION 17b. — *Manner in which these arrangements are obtained.*

On the following Railways, these arrangements are obtained by means of electric interlocking apparatus locking the levers : *Danish State, Hungarian State, Netherlands, Polish State, Stockholm-Västeras-Bergslagen* and *Czechoslovak State*. In the only power-operated signal box of the *Helsingborg-Hässleholms Ry.* this arrangement is obtained by means of relays cutting the energy to the points or signals to be locked.

Both methods are used by the *Finnish State Rys.*, and in Sweden by the *Stockholm-Roslag* and the *Varberg-Boras-Herrljunga Rys.* In two power-operated signal boxes of the latter Railway the levers are mechanically interlocked, and in eight signal boxes the levers are interlocked by means of relays.

QUESTION 17c. — *Control devices in the signal box, viz. :*

1. *Signal control (checking the line clear or danger indications);*

2. *Point control (checking the position of the points);*

3. *Control of correspondence (checking correspondence);*

4. *Track circuit control (indication of occupancy of track circuits).*

All these methods of control are used on the *Danish State Rys.*, *Netherlands Rys.* (1 only for the danger indication), *Polish State Rys.* (4, for most boxes), *Varberg-Boras-Herrljunga* and *Czechoslovak State Rys.*

The *Reichsbahn*, *Finnish State Rys.* and the *Stockholm-Västeras-Bergslagen* and *Helsingborg-Hässleholms Rys.* do not mention the use of control of correspondence. The *Stockholm-Roslag Ry.* uses signal control and control of correspondence.

QUESTION 17d. — *Among the devices described under (a) and (c) above, which do you consider indispensable in all power boxes? Which do you consider indispensable only for signal boxes controlling wide areas, where it is difficult or impossible for the signalman to have a direct view of the track.*

The *Deutsche Reichsbahn* states that all the devices mentioned under (a) and (c) — with the exception of the sectional route release and the automatic setting to line clear of the signal — exist in all power-operated signal boxes and are considered indispensable. Sectional route release and automatic clearing of the signal are added only where necessary, owing to local conditions.

The *Danish State Rys.* state that in their opinion the following should exist in all signal boxes: constant indication locking of the position of points and signals; signal position control; control of correspondence; and in signal boxes controlling wide areas: point locking, sectional locking and indication of occupancy of track circuits.

The *Finnish State Rys.* consider that point and signal indication control in mechanical control apparatus, and constant control in electric control apparatus are essential; circumstances will dictate the use of other apparatus.

The *Netherlands Rys.* consider that it is essential to obtain a control over the danger indication of the signals and, in the case of signal boxes controlling large areas, route control, switch position control and control of correspondence.

Automatic protection devices, approach devices and those indicating the occupancy of track circuits, are not considered indispensable by the *Polish State Rys.*

The same applies to the *Stockholm-Roslag Ry.* insofar as the signals, route interlocking, approach device, point position control and track circuit control are concerned; for large stations, the locking of the points and the repetition

of the signal indications in the signal box are also considered indispensable.

The other Railways have not supplied any definite information on this subject.

QUESTION 17e. — *Measures to be taken in case of failure. Is it necessary always to call up the maintainer or are the installations provided with cancellation devices for use by the signalmen in case of failure? In this latter case, are the signalmen allowed to use these cancellation devices on their own authority, or must authority be obtained from a higher grade official? Is this cancellation self-restoring?*

On the *Halmstad-Nässjö, Helsingborg-Hässleholms* and *Varberg-Boras-Herrljunga Rys.* the maintainer is called in case of failure. The latter Railway, which has ten power-operated signal boxes, states that it has no cancellation device for use by the signalman. In one of the signal boxes of the *Stockholm-Västerås-Bergslagen Ry.* a time release is used for route cancellation.

On the *Danish, Finnish, Hungarian, Netherlands, Polish* and *Stockholm-Roslag Rys.*, these installations have cancellation devices for use by the signalman. On the *Danish, Netherlands, Polish* and *Czechoslovak Rys.*, the cancellation is carried out by the signalman on receipt of authority from a higher grade official. In *Poland*, such authority is given by the station master, and, in *Czechoslovakia*, by the assistant station master.

On the *Stockholm-Roslag Ry.*, the higher grade official is informed of this cancellation, without his previous authority being necessary. In *Finland*, the use of this cancellation device is simply noted in the register.

On the *Polish State Rys.*, this cancellation is not self-restoring; the other Railways have supplied no information on this subject.

The *Reichsbahn* gives the following data. When a switch is out of order, the locks must be removed from the point

lever; the point must be operated by hand by means of a lever and locked by a clamp. The signal can then only be cleared for a train movement if the point detection device is in good condition, only the point operating device being out of order. In this case, the signal can only be operated upon special authority from the train controller. If the signal does not go to *line clear* although all the necessary conditions exist, and the route signal lever is in the position of completed stroke, and if the failure cannot even be remedied by the replacement of the locks, the trains must only run on written authority or hand signals.

QUESTION 17f. — *In case of failure, do you compel the driver to stop before proceeding?*

In Holland, Poland, Czechoslovakia and on the Swedish Rys. covered by this report, with the exception of the Stockholm-Västerås-Bergslagen Rys. in case of failure the train *must* stop before proceeding. The same applies to those cases where a failure prevents a point from being operated (the cancellation of the locking device is then necessary for operating the points) or prevent a signal from going to *line clear* (this signal can be passed by a train without stopping although it still displays the *danger* aspect).

In Denmark, these regulations are only applied to certain specific cases.

II. — Control at long distances.

None of the Railways mentioned in this report have installations of this kind.

The Czechoslovak State Rys. state that, on principle and chiefly for safety reasons, and taking into account the experience acquired abroad, they do not allow trains to run in both directions on double track lines unless one track only is used. This Railway is of the opinion that the additional equipment required

to ensure safety in train operation when both tracks are being used for traffic in both directions, would be very complicated, costly and uneconomical.

Automatic control.

Automatic control of points and signals other than automatic block signals, for instance the automatic operation of the signals protecting the crossing of two lines on the level when a train is approaching.

The Deutsche Reichsbahn states that in its large shunting yards it uses installations allowing the automatic operation of the points on splitting tracks in order to accelerate shunting operations, and that the number of failures is very small.

* * *

CHAPTER III.

Locomotive cab signals.

Automatic braking.

The last part of the Questionnaire dealt with cab signals, continuous indication signalling, signal repeating devices, and automatic braking devices.

Only the Deutsche Reichsbahn uses automatic train control, about which it has supplied the following information.

The length of lines equipped with automatic train control with *speed control at given points* (warning and stop signals, speed restrictions, etc.) is as follows :

Mechanical control .	325 km. (202 miles);
Inductive control .	3 500 km. (2 175 miles);
Optical control . .	75 km. (46.6 miles).

The lengths of single-track lines included in the above figures are as follows :

Mechanical control .	—
Inductive control .	60 km. (37.3 miles);
Optical control . .	—

Number of steam and electric locomotives and rail motor cars equipped for :

Mechanical control . . . 1350
 Inductive control . . . 140

The ratio of the total number of locomotives and rail motor cars equipped with automatic control to the total number of locomotives owned by the Railway is 1500/22000. The percentage of locomotives and rail motor cars equipped for automatic train control equals 7 %.

The *Reichsbahn* are continuing to equip lines with automatic train control, and are equipping at the present time :

300 km. (186 miles) of line with inductive control;

350 km. (217.5 miles) of line with optical control;

160 locomotives for inductive control;
 2 locomotives for optical control.

The locomotive equipment is checked before the commencement of each journey. The drivers are not compelled to reduce speed when it becomes necessary to put the apparatus out of service due to some failure or damage.

The number of failures is very small; on lines equipped with apparatus for inductive control, for every hundred movements there are :

Incidents due to the apparatus failing to work :

Track equipment	} 0.000
Locomotive equipment . .	

Incidents due to untimely working of the apparatus :

Track equipment	} 0.006
Locomotive equipment . .	

On lines equipped with automatic train control, automatic braking only takes place when the driver is not on the alert.

The *Czechoslovak State Rys.* are at present trying these new devices, the price of which, however, they think is too high in view of the financial position of the railways.

The opinion of this Administration on the question of automatic train control and automatic train stop, has been published in the *Bulletin* of the Railway Congress, December 1929 number (Report by Mr. Kristensen, Question IX, Madrid Congress).

* * *

SUMMARY

Automatic Block.

The replies received from the Railways covered by this report show that automatic block is not widely used, the percentage of lines equipped with this kind of installation varying between 0.07 % and 2.6 % of the total length of lines, while the length of lines equipped with non-automatic block represents from 10 % to 100 % (*Finnish State*) of the total. This state of affairs is justified insofar as the *Czechoslovak State Rys.* are concerned by the necessity for retaining the absolute block system, and the large number of level crossings, the barriers of which are mostly operated by signalmen, which represents a great economy.

We have thought it of interest to repeat below certain remarks made by the *Deutsche Reichsbahn*.

« The automatic block system is generally preferable to the manual system with signalmen, in those cases where the working involves staff difficulties and where local conditions are unfavourable. In remote districts where traffic is light it is not advisable to employ men for the purpose of ensuring the proper working of the block system. As is known, the manual block system has been installed and is kept up where reliable staff is available and where, on the other hand, the salaries are relatively low. But where these conditions did not exist, as for instance in the United States of America, the traffic required the development of the automatic block system. Those Railways which have used the manual block

can use to advantage the automatic block system, where the nature of the territory presents unfavourable conditions as regards maintenance and supervision, as, for instance, cuttings, tunnels, or bridges, etc., where it is usually very difficult to house employees. Such is, in particular, the case for the establishment of intermediate block posts between stations in case of an increase in the train density. This combination of signalling systems does not present any difficulties. The automatic block system, however, is absolutely necessary for the protection of underground and suburban railways with high train frequency. In this case, experience has proved that, in the long run, manual operation of signals and block apparatus will allow a higher train frequency (trains running every few minutes) only if the staff is very efficient. It is necessary today to provide a service with trains running at intervals of one-and-a-half minutes, which would be badly handicapped by slowness in the case of manual operation. Furthermore, the signalmen run the risk of becoming automatons, of very uncertain efficiency. »

Of the lines equipped with automatic block signalling, the greater part — almost two-thirds — have day-light signals.

As the colour of the lights, their number and arrangement, as well as the shape of the mechanical signals, vary so much between the Railways covered by this report, it is difficult to recommend any specific system. Only as far as the protection of junctions is concerned, all the Railways agree in that the junction signal should be used as block signal; the method of signalling, however, differs from one Railway to another.

The average length of the block sections varies between 0.5 and 6 km. (0.31 to 3.7 miles) and depends upon the number of trains.

The signal is put to danger when the

first pair of wheels passes except in *Denmark*, where it is put to danger by the last pair. The preceding signal is set to *line clear*, according to the Railway, either when the next signal goes to danger or when the end of the train has passed the latter by the braking distance.

On nearly all the Railways consulted, the normal position of the signal is the *line clear* position. Approach lighting of day-light signals is used only on the *Stockholm-Roslag Ry*. Flashing lights are only used in *Denmark*, and partially in *Sweden*, for warning signals.

On the majority of Railways, the train which has been stopped by a block signal at *danger*, may proceed after receipt of authority by telephone from the next station. No exception is made for sections over steep gradients. After passing a block signal at *stop*, the engine driver must proceed with caution at a speed varying between 15 and 20 km. (9.3 to 12.4 miles) per hour according to the Railway; on certain Railways he must proceed at sight and be able to stop immediately on sighting an obstacle.

The station home signal is combined with the block signal and, if at danger, cannot be passed unless authority from the nearest signal box has been received. Protection of a stopped train is considered sufficiently ensured by the block under ordinary conditions. On various Railways, in the case of a prolonged stop (for instance, ten minutes), or in case of an accident or failure, an additional protection at a distance of 800 to 900 m. (2 625' to 2 960') is prescribed.

The majority of Railways do not consider it necessary to take special precautions against the possible failure of a block relay, i.e. if the block relay remains energized. Most of the Railways — with the exception of the *Reichsbahn* — allow their light-weight rolling stock to run on lines equipped with automatic block signalling, except trolleys with insulated axles. The Railways covered by this report have no automatic block

installations operated by other means than track circuits.

Insofar as failures of automatic block signals are concerned, the replies received to our Questionnaire show that these failures are very rare, so much so that the *Deutsche Reichsbahn* does not consider it worth while preparing special statistics thereof. On the *Netherlands Rys.* there was 0.14 failure per signal in 1933. No Railway has experienced the case where a signal remained at *line clear* in spite of the section being occupied, so that this method of signalling can be considered quite safe in this respect.

From the information obtained it can be inferred also that the engine drivers observe the regulations and that there has been no case of penetration at an excessive speed into an occupied block section.

Climatic conditions apparently do not cause great difficulties in the operation of automatic block signalling. In this respect certain observations should be mentioned : The *Polish State Rys.* are of the opinion that in cold weather the feed to the track circuits should be reduced and, furthermore, that rail creep may endanger the insulated joints. The *Stockholm-Roslag Ry.* has experienced certain difficulties in the insulation between block sections, due to the expansion and contraction of the rails by high day and low night temperatures.

Distant control.

Power-operated signal boxes.

Among the various types of power boxes, the electric are the most used. There are fifty electro-pneumatic boxes in Germany and one only in Poland.

One power box controls between 12.7 and 5.45 km. (7.9 and 3.38 miles) of lines. The number of power boxes represents from 0.6 to 13 % of the total number of interlocking boxes.

All the power boxes mentioned have individual levers, the form of these levers

varying according to the Railway. There are ordinary levers, hand levers and push-buttons, so that it is difficult to make any definite recommendation on this subject.

Mechanical interlocking between levers is evidently mostly favoured by the various Railways. Electric interlocking by means of electric interlocking apparatus locking the levers is employed on a smaller scale. Electric interlocking by means of relays, cutting off directly the current to the points or signals to be locked without affecting the levers themselves, is more unusual still.

In case of failure the points are hand-operated (on certain Railways by locking them with clamps) and hand signals are used in this case, or exceptionally the trains are piloted.

The replies received relatively to the safety devices which are considered useful, allow the following statements to be made.

The majority of Railways use *indication locking*, i.e. a device preventing a lever from finishing its stroke unless the point or signal has actually been operated.

All Railways, with the exception of two Swedish Railways, use this indication locking for the points and signals. The device works permanently, the signal going automatically to *danger* if a point or signal fails to follow the movement of the lever.

In the majority of cases, *switch locking* is also used, i.e. a switch is prevented from being operated whilst being passed over by a train.

Section locking, i.e. device by which a signal at stop giving access to a portion of the track cannot be set at *line clear* unless this portion is actually free, is not generally used. This section locking is resorted to in several cases, especially where the tracks involved are not sufficiently visible from the signal box.

Route locking or *traffic locking*, i.e. an arrangement by which the stop indication of a stop signal in the rear of a

train which has not run through its entire route does not allow the setting of a conflicting route, exists with very few exceptions in all the signal boxes of the Railways covered by this report. It is generally obtained by means of track circuits. Less frequent are the installations of this kind using mercury or mechanical contacts. In addition to track circuits the *Reichsbahn* uses the release by means of push-buttons, operated by hand from an independent signal box from which the visibility of the route in question is good.

Complete route release is the most general, sectional route release being used only in very large sections.

The cancellation of the route for shunting movements is not widely used and exists only on the *Halmstad-Nässjö* and *Varberg-Boras-Herrljunga Rys.*

Approach locking, i. e. a device by which, after a route «A» has been set, a conflicting route «B» cannot be set — after the signals of route «A» have returned to danger — unless the signalman is absolutely positive that the train expected on route «A» will have sighted the distant signal at danger, exists only partially on three Railways and is obtained by means of track circuits or in conjunction with mercury contacts.

The use of electric interlocking apparatus between levers is more prevalent than the use of relays cutting the feed to the points and signals to be locked.

With few exceptions the Railways provide their signalmen with the following means of control : control over the *danger* and *line clear* indication of the signals (*Netherlands Rys.*, control over the *danger* indication only); point control; control or correspondence and track circuit control.

Among the safety devices previously enumerated, the Railways consider the

following particularly useful : constant indication locking of the position of the points and signals, automatic protection of occupied tracks and route locking.

On the majority of Railways these installations have cancellation devices for use by the signalman in case of failure, and in most cases the signalman is only allowed to use them after receipt of authority from a higher grade official. On approximately half of the Railways the engine drivers are compelled to stop before proceeding.

Control at long distances.

As none of the Railways mentioned in this report have installations of this kind, we cannot make any observations on this subject.

Automatic control.

Automatic point control devices are used only in large shunting yards of the *Deutsche Reichsbahn*. Their working is satisfactory and failures seldom occur.

Locomotive cab signals.

None of the Railways mentioned in this report repeat the position of the signals on the locomotive. Automatic braking with speed control at given points (warning and stop signals, speed restrictions, etc.) is used on the *Reichsbahn* with mechanical, electrical or optical transmission.

The mechanical devices are used apparently on underground and suburban railways; the others on long-distance lines.

From information given earlier in this report it can be seen that the optical systems are used as much as the electrical devices, judging from the length of lines on which these devices are now being installed.

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

13th SESSION (PARIS, 1937).

QUESTION X.

Effects of the world crisis and road competition on the railway position. Corresponding changes in railway commercial policy.

REPORT

(All main-line Railways affiliated to the International Railway Union [U.I.C.],
except the four British main-line Railways),

by Dr. COTTIER,

Manager of the third District of the Swiss Federal Railways,

and Dr. TRIERENBERG,

Reichsbahnoberrat, German State Railways.

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Preface.

In accordance with a resolution passed by the Permanent Commission on 29th July 1933, the aforesaid reporter, in collaboration with the late Reichsbahndirektor von BECK, of the German State Railways, deceased at the end of December 1936, was entrusted, in 1934, with the drawing up of a first report on the « The World Crisis and Railways ». The Headquarters of the German State Railways appointed Dr. TRIERENBERG, Reichsbahnoberrat, as joint reporter in the place of Reichsbahndirektor von Beck,

The main report, which is a description of the development of the world crisis and railways traffic in the years 1929

to 1932, was published in the December 1934 issue of the *Bulletin* of the Railway Congress. As a supplement to the main report, there appeared in the September 1935 issue of the *Bulletin* an additional report in which the enquiry covered the years 1933 and 1934.

Although it has since become more and more evident that the general economic trend of the last few years should not, strictly speaking, be included in the term « World Crisis », as it is due in many respects to structural changes in the world economic conditions, the present report bears the same heading as the previous ones. The object is to present here a comprehensive review of the general economic development

from 1929 to 1935 and, as far as data are available, of the tendency during the first half of 1936, as well as its repercussions on railways.

* * *

CHAPTER ONE.

Railways and general economics.

I. — The general economic trend from 1929 to 1935.

At the commencement of our report, published in the September 1935 issue of the *Bulletin of the Railway Congress*, when reviewing the general economic situation, we pointed to the fact that the ever increasing downward trend of the world's economic situation, after the 1929 boom, had been checked in 1933 and 1934 and that there was a business revival in certain countries.

During 1935 the economic development — which, however, was still mostly

confined to home markets in every country — made considerable progress. Admittedly, in such countries as Great Britain, Germany, Sweden and Japan, where a decided improvement made itself felt already in 1934, the upward trend slackened somewhat in 1935. On the other hand, the improvement is more pronounced in other countries which had not hitherto been able to overcome the effects of the world crisis. According to a report issued by the International Labour Bureau, a marked improvement of the economic situation has made itself felt in some three quarters of the world. Thus, whereas in 1935 the group of countries, whose economic situation was constantly or gradually improving, became widened, in those countries which held on longest (till end of September 1936) to the gold standard, viz. France, Holland and Switzerland, the crisis continued and sometimes became even worse in 1935 and 1936.

World quantitative production, 1929 to 1935.

(According to the *Monthly Statistical Bulletin of the League of Nations.*)
(1929 = 100.)

Year.	Industrial world production.	Coal.	Lignite.	Crude iron.	Crude steel.
1929	100	100	100	100	100
1930	90	91	84	81	79
1931	81	80	77	56	58
1932	72	71	72	40	42
1933	81	74	73	50	56
1934	89	81	78	63	68
1935	99	83	82	74	82

The industrial world-production, which had steadily increased until the crisis started and since then constantly decreased, until it only amounted in 1932 to 72 % of the capacity in 1929, has during the last three years decidedly increased again and in 1935 it almost reached the highest point recorded be-

fore the crisis broke out. In comparison to the low production level of 1932 the quantitative increase up to the year 1935 amounts to 38 % as regards industrial world production, 85 % for crude iron and in the case of crude steel as much as 95 %.

Industrial production.

(According to the Monthly Statistical Bulletin of the League of Nations.)
(1929 = 100.)

—	1929	1930	1931	1932	1933	1934	1935
Germany	100	86	68	53	61	80	94
France	100	101	89	69	77	71	67
Italy	100	92	78	67	74	81	92 ⁽¹⁾
Austria	100	85	74	64	66	72	80
Belgium	100	89	82	69	71	72	81
Holland	100	91	79	62	69	70	66
Great Britain	100	92	84	83	88	99	106
Denmark	100	108	100	91	105	117	121
Sweden	100	96	84	79	82	100	107 ⁽²⁾
Norway	100	101	78	92	94	98	105
Hungary	100	94	87	77	84	98	111
Czechoslovakia	100	89	81	64	60	66	70
Poland	100	82	70	54	56	63	66
Japan	100	95	92	98	113	129	142

(¹) January-August.
(²) January-May.

After the depression started, there was an almost general and decided drop of industrial production, which in the case of the majority of States reached its lowest point in 1932. In the succeeding years a decided industrial improvement became perceptible in most countries, increasing in intensity until 1934, continuing in the last few years, even if partly, at a somewhat slower rate. The industrial improvement especially persists in Germany and then in Great Britain, Den-

mark, Sweden, Norway, Hungary and Japan, where the production volume has already, sometimes considerably, exceeded the 1929 peak, whereas in France and Holland industrial activity decreased further.

The economic developpement in the last few years is also clearly indicated by the *unemployment figures* of each country, as is proved by the following table, resulting from our enquiry :

—	1934	1935	1936
Germany	4 059 000	2 605 000	1 098 000
France	341 053	425 675	462 760
Austria	311 445	294 074	279 610
Switzerland	65 440	82 468	97 778
Belgium	223 300	163 300	168 017
Holland	320 300	320 300	378 800
Denmark	87 114	79 603	85 173
Sweden	114 802	61 581	46 565
Norway	37 439	36 103	35 876
Portugal	28 000	42 000	42 000
Hungary	60 000	49 000	38 000
Czechoslovakia	—	98.1	91.2
(Index : 1933 = 100).			
Jugoslavia	300 952	361 614	216 454
Bulgaria	32 382	37 177	46 898
Japan	374 318	356 557	343 426

The above figures cannot be compared as regards the various countries, as some of the returns only include wholly unemployed and others partly-unemployed; furthermore, some returns are based on figures handed in on certain dates, whilst others represent average figures for a year or six months. The table, however, clearly shows the variations in unemployment, viz. increase or decrease, for the various countries. A decrease is shown above all in Germany, Sweden, Austria and Hungary; in Finland unemployment had even become insignificant in 1936. On the contrary, the increase in unemployment is still marked in the case of France, Holland and Switzerland.

A further symptom of the economic improvement in latter years is to be found in the much increased output of automobiles throughout the world since the year 1929 :

World production of motor cars.

(Passenger cars and lorries).

1929	6 278 000	100
1930	4 127 000	66
1931	3 049 000	48
1932	1 977 000	31
1933	2 683 000	43
1934	3 749 000	60
1935	5 128 000	82

World industrial production and world commerce.

Quantitative industrial production. Quantitative world commerce.
(1929 = 100.)

1929	100	100
1930	90	93
1931	81	86
1932	72	74
1933	81	76
1934	89	76
1935	99	78

The above comparison between the development of industrial production and of world commerce, shows that during the first years of the crisis world production and world commerce shrank practically to the same extent. Since 1933, on the contrary, we see that whereas production rose considerably, there was only a moderate rise in the commercial turnover. Whereas production increased 38 % from the lowest record in 1932 to 1935, the imports and exports only increased by 5 % during the same period. We shall go hereafter into the causes of this phenomenon.

World trade, 1929 to 1935.

(Imports and exports in millions of Swiss francs.)

Year.	Europe.		Other continents.		World trade.	
1929	180 176	100	132 264	100	312 440	100
1930	153 972	85	96 705	73	250 677	80
1931	115 168	64	63 796	48	178 964	57
1932	76 695	42	48 194	36	124 889	40
1933	69 024	38	43 768	33	112 792	36
1934	65 019	36	42 657	32	107 676	34
1935	64 324	36	45 645	34	109 969	35

As a result of the progressive aggravation of the crisis, of the far reaching changes in the whole structure of world economics and of the commercial difficulties, which grow from year to year, owing to international commercial relations being hampered by commercial policies, world trade continued to recede until it reached the lowest ebb in 1934. Within the short space of time from 1929 to 1934 the total world-trade decreased, expressed in terms of gold, by 66 %, whilst the export trade of European countries suffered to the extent of 64 %, and of countries other than European as much as 68 %. In connection with the much increased industrial activity and the rising tendency of world market prices, the value of the world trade showed a slight improvement in 1935, which, it is true, only applies to extra-European countries, whereas in European countries the drop in trade had almost come to an end. Although the rise in value of world trade was only very modest, it appears all the more important because it was the symptom of a sudden change in the evolution of world trade and a change for the better in the realm of international commercial dealings.

The far reaching effects of the world crisis and of hindrances (due to commercial policies adopted) to a widespread exchange of goods between countries are shown in *Tables 1 and 2* at the end of the present report; these tables give the quantitative exports and the value of same for the various countries, expressed in their respective currencies.

The quantitative export trade, which in almost all countries reached its lowest level in 1932 and 1933, improved notably in the succeeding years in a number of

countries, but it suffered a fresh setback in 1935 in all countries for which statistics are available; in some cases this relapse occurred slowly. In other countries, on the contrary, the crisis which had lasted already for years continued on a still worse scale. As regards the development of the value of foreign trade, the decline, in all countries up to 1932, corresponded more or less with the relative value of their currencies. In the following years a change in development can be noticed because in those countries whose currencies had been depreciated, exports showed a marked increase as regards their value, whilst in those countries which adhered to the gold standard the shrinkage in value still continued.

As we already pointed out in our 1935 report, when judging the development of the value of export trade, expressed in the currencies of each country, it should be borne in mind that when converting the value of export trade, expressed in local currencies, into gold, viz. a standard for international comparison, there was even in countries having a depreciated currency a real drop in value of exports up to 1934 and it was only last year that a modest improvement occurred in several countries (see Table 3 concerning value of exports in Swiss francs, former currency).

The rise during the last few years of the value of exports in the national currencies of countries having a depreciated currency is, in addition to a rise of the quantitative volume of trade, also due to a rise of world market prices in such countries, whereas in Switzerland the tendency of wholesale prices to drop only ceased last year, whilst in France and Holland it still continued.

Index figures for wholesale prices.
(1914 = 100).

—	1929	1930	1931	1932	1933	1934	1935
Germany	137	125	111	97	93	98	102
France	127	113	102	87	81	76	69
Italy	131	112	93	85	77	75	85 ⁽¹⁾
Austria	130	117	109	112	108	110	110
Switzerland	141	126	110	96	91	90	90
Belgium	123	107	90	77	72	68	77
Holland	142	128	109	92	90	90	88
Great Britain	137	119	105	102	102	105	106
Denmark	150	130	114	117	125	135	139
Sweden	140	122	111	109	107	114	116
Norway	149	137	122	122	122	124	127
Spain	168	167	169	167	159	163	163
Hungary	121	96	95	92	76	79	90
Czechoslovakia	117	104	94	87	84	87	90
Japan	166	137	116	122	136	134	140

(¹) January to October.

According to the calculations of the « Statistische Reichsamt » (German Statistical Department), the international movement of prices in the world's markets is as follows :

Index figures of world market prices (gold-index).
(1929 = 100.)

Year.	Total index.	Agricultural products.	Industrial products.	Raw materials	
				foodstuffs.	industrial.
1929	100	100	100	100	100
1930	78	75	84	78	78
1931	56	54	63	56	56
1932	44	42	51	46	43
1933	41	39	49	40	43
1934	39	37	45	37	41
1935	40	38	46	38	41

II. — The evolution of railway traffic in the years 1929-1935.

In consequence of the close relations between the industrial and commercial activity of a country and the traffic carried by its railways, the general economic trend is largely reflected by the volume of the traffic carried and the railway receipts as a whole.

Passenger traffic.

Evolution of passenger traffic.

(See Table 4).

As regards passenger traffic, there was no general and immediate drop as a result of the less favourable economic position. Several Railways were able to report an increasing passenger traffic

which was only interrupted by a sharp drop in 1931. After 1933 many railways were able to report a slowing down of the drop in traffic. Others, and above all the State Railways (Reichsbahn) in which were incorporated the Saar Railways on 1st March 1935, as well as the English main-line Railways, the Danish State Railways and the Swedish State Railways, were able to show a decided increase in traffic, whereas in particular in the case of the French main-line Railways, the Swiss Federal Railways and

the Netherlands Railways, the traffic is still falling off.

As will be seen from the following table, under the influence of the world-wide crisis, the much lessened purchasing power of almost all classes of people and the increasing competition of road traffic, all the Railways included in our enquiry report a considerable change-over from 1st and 2nd class to 3rd class. This evolution has also been hastened by the increasing comfort of the cheaper-class carriages.

Percentages of passengers carried in each class.

—	1929			1934		
	1st class.	2nd class.	3rd class.	1st class.	2nd class.	3rd class.
Deutsche Reichsbahn . . .	0.03	7.08	92.89	0.01	4.56	95.43
French main-line Rys. . . .	2.78	13.33	83.89	2.12	14.60	83.28
Italian State Rys.	2.16	10.69	87.15	1.35	8.68	89.97
Austrian Federal Rys. . . .	0.13	1.88	97.99	0.06	0.98	98.96
Swiss Federal Rys.	0.28	4.79	94.93	0.09	3.75	96.16
Belgian National Rys. Co. . .	0.53	8.25	91.22	0.25	7.04	92.71
Netherlands Rys.	2.50	15.63	81.87	1.57	11.20	87.23
British main-line Rys. . . .	5.19	2.20	92.61	3.82	1.76	94.42
Danish State Rys.	—	5.30	94.70	—	2.43	97.57
Swedish State Rys.	0.07	2.55	97.38	0.04	1.76	98.20
Norwegian State Rys. . . .	0.03	0.91	99.06	0.02	0.83	99.15
Spanish main-line Rys. . . .	4.68	7.91	87.41	2.99	5.88	91.13
Hungarian State Rys. . . .	0.28	13.77	85.95	0.03	8.94	91.03
Czechoslovak State Rys. . .	0.02	1.44	98.54	0.01	1.04	98.95
Polish State Rys.	0.07	5.57	94.36	0.03	4.87	95.10
Jugoslav State Rys.	0.10	2.78	97.12	0.07	1.74	98.19
Japanese Govt. Rys.	0.01	1.45	98.54	0.01	0.80	99.19

Receipts from passenger traffic.

(See Table 5).

As a result of the crisis, receipts from passenger traffic fell considerably from 1929 to 1933, although the drop in receipts did not make itself felt at the same time nor to the same extent for all the Railways. Whereas, in the case of a few Railways, receipts still continued to rise during the first year of the crisis, an immediate drop in receipts, which contin-

ued till 1933, made itself felt in the case of most Railways, the German State Railways, the Austrian Federal Railways, the Italian State Railways, the Netherlands Railways, the Hungarian State Railways and the Polish State Railways being particularly hard hit in this respect. Since 1934, and for a few Railways since 1933, a decided rise in passenger receipts was reported : in particular by the Deutsche Reichsbahn, the Swedish State Railways and Danish State Railways, and last year

also by the Belgian National Rys. Co. On the contrary, receipts on the French main-line Railways, on the Swiss Federal Railways, Netherlands Railway and Yugoslav State Railways still continue to drop. As we already pointed out in our 1935 report, during the crisis years the receipts from passenger traffic showed a much greater drop in almost all instances than the corresponding numbers carried, for which sufficient explanation is to be found in the continued change-over of passengers travelling in a cheaper class and keener road competition as regards passenger traffic.

Goods traffic.

Evolution of goods traffic.

(See Table 6).

Goods traffic, particularly sensitive to the crisis, was hit quicker and harder than passenger traffic. The drop here took place immediately after the start of the crisis and continued, on a constantly increasing scale, till 1932. It was particularly felt by the German State Railways, the Austrian Federal Railways, the Belgian National Rys. Co, the Swedish State Railways and Czechoslovak State Railways, whose goods traffic, reckoned in tonne-kilometres, dropped by almost half from 1929 to 1932. The following years brought about a change in the previous constant fall, inasmuch as under the effects of national economic improvements the fall in traffic slowed down somewhat in 1933, whilst it was partly wiped out in the last two years by a livening of traffic on other lines.

The inter-dependence which generally exists between goods traffic by rail and the position of export business is shown by Table 7 comparing the evolution of the goods traffic of the various Railways and imports and exports of their countries.

Goods receipts.

(See Table 8).

Parallel to the falling-off of goods traffic, which commenced immediately after the start of the crisis and continued till 1932/33, goods receipts, which form a category of receipts that is particularly sensitive to fluctuations of the economic situation, suffered a severe setback. The falling off of this traffic had in particular unfavourable effects on the financial resources of the German State Railways, the Italian State Railways, the Polish State Railways and the Czechoslovak State Railways, in the case of which goods receipts dropped up to 1933 to about half of the figures for 1929. The effect of the traffic crisis was somewhat less felt on the Austrian Federal Railways, the Netherlands Railways, the Swedish State Railways, the Hungarian State Railways, the Yugoslav State Railways and the Belgian National Railways Co.; the receipts of these Railways nevertheless fell about 30 to 40 % during the same period.

As the result of the improvement of business and traffic, receipts again commenced to rise on most Systems, notably on the German State, Swedish State, Hungarian State and the Yugoslav State Railways, whereas, on the contrary, on the French main-line Systems, the Netherlands Railways, the Swiss Federal Railways and the Spanish main-line Railways, the drop in receipts continued and in some cases it even became aggravated. In the case of the Belgian National Railways Co. the falling-off continued up to 1935, whilst in 1936 a decided upward movement made itself felt.

The following comparative table shows that on most of the systems, goods receipts felt the effects of the crisis to a much greater extent than passenger receipts, which is explained by the greater falling off goods traffic and by competition from motor lorries, which is particularly keen as regards goods transport.

Relative decline in traffic receipts from 1929 to 1936.

	Receipts.		
	Passenger traffic. %	Goods traffic. %	Whole of the traffic. %
Deutsche Reichsbahn	— 29.8	— 33.1	— 32.4
French main-line Rys.	— 15.4	— 42.8	— 36.3
Italian State Rys. ⁽¹⁾	— 31.7	— 50.1	— 43.9
Austrian Federal Rys.	— 37.4	— 34.8	— 36.0
Swiss Federal Rys.	— 19.1	— 27.7	— 24.6
Belgian National Rys. Co.	— 12.3	— 45.6	— 37.5
Netherlands Rys.	— 36.3	— 51.6	— 44.3
British main-line Rys.	— 13.4	— 19.0	— 16.2
Danish State Rys.	— 3.9	— 23.4	— 9.1
Swedish State Rys.	— 8.6	— 16.6	— 7.8
Norwegian State Rys.	— 6.8	— 17.3	— 13.4
Spanish main-line Rys.	— 13.8	— 14.0	— 14.2
Hungarian State Rys.	— 35.2	— 37.0	— 36.2
Czechoslovak State Rys.	— 29.6	— 41.4	— 38.9
Polish State Rys.	— 47.0	— 46.2	— 46.5
Jugoslav State Rys.	— 33.5	— 24.3	— 26.8
Japanese Govt. Rys. ⁽¹⁾	— 2.0	+ 2.8	+ 2.5

(¹) 1929-1934.

III. — Mutual reactions between railway traffic and the economic situation.

As long as railways had in most countries a practical monopoly as regards transport on land, economic activity was necessarily bound to be directly reflected in their traffic returns. When goods were mostly able to be freely exchanged between countries in the pre-war years, the circulation of products beyond the frontiers gave a fairly exact idea of goods traffic as a whole and hence of economic activity. Thus, there is nothing astonishing in the fact that there has always been almost complete relativity between the two categories of statistics. The reason for which it was the custom to compare railway goods traffic with export trade figures lies solely in the fact that movements of goods beyond political frontiers could be determined with exactitude, whereas for the circulation of products within countries one had to be satisfied with more or less approximate estimates.

As long as goods could be freely exchanged between States, the figures for export trade could be considered as a barometer of the general economic situation. But this state of affairs alters when various countries erect artificial barriers to international trade, and that is precisely what has occurred on an increasing scale for the last few years. A tendency has more and more made itself felt to restrict imports of goods as much as possible and to replace them by goods produced in the country itself. Shortage of foreign currencies due to the financial policy adopted, motives of ultra-protectionism and the schemes to foster and subsidise various branches of home-trade have all helped to a large extent to strangle international exchange of goods.

The result of this economic evolution is clearly revealed in the table on page 1113/53, in which the quantitative world industrial production is compared with the world's quantitative trade. Whereas the index number of world production—

the year 1929 being taken as the basis = 100 — already reached the figure of 99 in 1935, or practically the level of the last prosperous year before the world crisis, the index number for world trade remained stationary at 78 and consequently only exceeded the low level of 1932 by 4 points. This shows clearly that world trade only benefited to a slight extent from the economic recovery which took place in a number of countries since the lowest ebb of the crisis.

There is no doubt that navigation has been hardest hit by this situation. But as regards railways also, the conclusion may be drawn that since the beginning of the crisis organic changes of general economics have occurred which entail permanent reduction of their former basic traffic.

By means of an intensification of the various home industries tending towards the country becoming self-supporting, that disadvantage might be offset to the extent to which home traffic will then increase (in small units and over shorter distances, it is true), provided same is not captured from the railways by motor traffic. The proof that this compensation can be obtained in itself is supplied by the report of the Italian State Railways. This Administration points out that, as a result of the economic sanctions taken against Italy, export trade declined a good deal at the end of 1935 and the beginning of 1936. In spite of that, the Italian State Railways show for the present year an increase in their goods traffic (as well as of their passenger traffic). Although this increase is partly due to the African campaign, the example shows that the former parallel evolution of the volume of export trade and of railway goods traffic does not necessarily exist any longer under the present circumstances of the economic structure. It is thus that the French Railways, for their part, notice that part of their national production intended for export has fluctuated in the last few years more considerably than the production of

industries working for home consumption.

Another typical example of the evolution which we have just mentioned is quoted in the reply from the Portuguese State Railways, in which the « Wheat Campaign » set afoot by the Portuguese Government is alluded to. Formerly, Portugal imported wheat. The annual production of wheat grown in Portugal itself amounted to 561 million litres in 1933, and to 840 million litres in 1934. In 1935 the crop still further increased and even exceeded the quantity required for home consumption, with the result that Portugal became a wheat exporting country.

For their part, the Hungarian State Railways state : « The consequence of the economic crisis and stagnation of export trade was that we had to seek the possibility of producing several articles ourselves, with the result that the requirements of the country were satisfied by home industries existing or newly created ».

Together with this evolution there is a corresponding industrialisation of overseas countries which formerly supplied raw materials and were also consumers of European manufactured products. These countries are striving more and more to make use of their raw materials on the spot and satisfy themselves the home requirements of manufactured goods. And thus the former outlets for European industrial countries are narrowing more and more.

A striking example of this kind is mentioned in the reply from the Morocco Railway Co., who points out that exports have declined in recent years as regards value, but not quantitatively. On the other hand, imports also drop as regards quantity, which, it states, is to be attributed to the progressive equipment of the Colony with appropriate means of production.

Finally, we would mention, in this connection, the economic evolution of Japan whose overseas trade, and espe-

cially its industrial exports, have constantly increased during the last few years. The industrial output of that country, as also its qualitative overseas trade, have exceeded the 1929 level considerably. This evolution was aided, above all, by its economic relations with the Manchukuo State, founded in 1932, and whose economic expansion has almost entirely benefited Japanese manufacturers. Thus, the Japanese Government Railways had, in 1935, an unprecedented traffic, which still continued to expand in 1936.

Changes in the economic structure which entailed a decline in the transport of merchandise occurred not only in the relations between European industrial countries and overseas countries which were formerly consumers, but also within the said European countries themselves. We need only remind our readers of the utilisation of water power which eliminates coal traffic and of the changes in the sites selected for factories, as a results of synthetic production of raw materials.

In addition to the large quantitative decline of world trade, the general evolution of prices had a great effect on railways. No doubt the world's industrial production has almost again reached the 1929 level; doubtless, certain countries have succeeded in extending their export trade, from a quantitative standpoint, beyond the 1929 stage; but almost nowhere has the value of export trade reached the pre-crisis level. This disparity between the evolution of values and that of quantities is clearly revealed if the values are expressed in non-depreciated gold currency. The most striking example of this is supplied by Japan. Its quantitative foreign trade amounted in 1935 to 129 % of that of 1929; in value it reached, in Japanese currency, 114 %; on the other hand, expressed in gold-francs of the former parity, the same level of values only amounts to 42 % of that of 1929. The decline of prices brought about by the worldwide econo-

mic crisis could hardly be better illustrated than by this example.

The consequence of this decline of values was that merchandise became much more sensitive to carriage charges. Added to competition from motor lorries which offer lower rates, this circumstance has also made itself felt on rail transport in the shape of a considerable lowering of rates. A characteristic fact in this respect is that on none of the railways which, thanks to the partial improvement of business had been able to report increased traffic during the last few years, did receipts rise to the same extent.

Owing to the large amounts of capital invested in railways, this fact is of all the more importance because certain Railway Systems have to face a load of debts on which the interest was able to be paid out of the 1929 receipts, but which a decided shrinkage of traffic and receipts was bound to render too heavy. As the same problem arose in respect of general economics, the growing disparity between the falling level of prices and debts based on the former price-level was probably one of the chief reasons which led numerous countries to depreciate their currencies. By this means it was possible to maintain the price-level and consequently to avoid a relative rise of the capital charges. This lightening of burdens, of which the Railways were not the only ones to benefit, has no doubt contributed towards business in general and with it also railway traffic in the older countries having a depreciated currency, reacting more rapidly. It should in any case be noted that until recently traffic continued its backward movement in those countries which held on longest to the gold standard, viz. France, Holland and Switzerland. The devaluation which was brought about in those countries at the end of September 1936 is still of too recent date to enable a final judgement to be passed as regards the effect of this measure on railway traffic.

In this respect, the results obtained by Belgium from depreciation are somewhat enlightening. The Belgian franc was depreciated, on 1st April 1935, by 28 %. Just as in the other countries on the gold standard, this measure was preceded by a lowering of prices and salaries and railway traffic declined. As regards goods traffic, the tendency to decline continued till 1935 included; but account must be taken of the fact that the Belgian Government decreed, on the 29th January 1935, a general reduction of goods rates. In the first half of 1936 a change occurred which is attributed to the improvement of business after depreciation. As to passenger traffic, the financial year 1935 showed an increase which will probably not continue in 1936; this fact is, however, probably due to the Brussels International Exhibition.

But on the other hand, the favourable effects of depreciations on the evolution of the economic situation should not be exaggerated. There is no doubt that the attenuation of the disproportion between the general level of prices and the debts with which the country's economic system is burdened eliminates a disturbing factor and that devaluation is temporarily capable of putting an end to the paralysing action of a continual fall of prices, to which one can foresee no end. On the other hand, it must be recognised that the unfavourable effects which instability of international currencies has on the evolution of world economics are much greater than the advantages which national economics may hope for in the long run, from repeated manipulations of their currencies.

Among the measures which nations have taken to stimulate general business, one should mention specially works carried out by the public authorities. From all countries without exception the replies are that the State has undertaken public works for the purpose of lessening unemployment. Special mention should

be made of the construction of motor highways in Germany. In addition, the German Government has built many workmen's dwellings; marshland has been rendered fit for cultivation and finally the German re-armament brought orders to all branches of its trade. In France the « Marquet Plan » was drawn up for the years 1934/10; the initial sum planned to be expended on this was 10 milliards of francs for public works. This sum was increased in 1936 to 20 milliards of francs, of which 4 for works on railways. The Italian Government has for years past earned a deserved reputation for its public works carried out on a large scale. In Belgium there was created an «Economic Reconstruction Office» (O.R.E.C.), the task of which is to study the carrying out of public works. A special mention ought to be made in this chapter of railway constructions in Czechoslovakia (better communications between the East and West of this country so drawn out lengthwise), in Yugoslavia, Bulgaria and Finland.

The economic revival which various countries have witnessed since 1933 is only partly to be attributed to natural tendencies to a rise; its cause lies, to a greater or lesser extent, in the above mentioned steps taken by the public authorities.

If, finally, we proceed to study the tendencies which directed the evolution of the situation in the various countries during the first half of 1936, the information supplied by the Administrations consulted enable us to ascertain the following characteristic facts :

In France traffic increased somewhat from a quantitative standpoint since the beginning of the year, but receipts remained below those of 1935. In Holland, also, the decline of traffic continues. It continued with particular acuity in Switzerland. In the first ten months of the 1936 financial year, goods traffic declined quantitatively 12.9 %; equally, goods receipts declined 13.5 % as compared with

the previous year. Passenger traffic also reveals a sharp decline.

In Germany, on the contrary, a revival of traffic continued during the first half of 1936. The passenger-kilometres increased 8 %, whilst goods tonne-kilometres show an increase of 12 %. Production for home consumption continues to increase. It is, above all, the building trade, mining industry, metal trade and the chemical industry which show signs of revival. Depressions have occurred from time to time in the textile industry, but they were attributable to a shortage of raw materials due to a lack of foreign currencies.

Owing to the rates reduction on 20th January 1935, in Belgium goods receipts have further declined that year, but the first half of 1936 shows an increase of 15 % in receipts, whereas the number of tonne-kilometres has increased by 20 %. Being an industrial country, Belgium is obliged to export in order to feed its dense population. It appears that the monetary depreciation has shown good results in that country.

In Austria, the figures representing traffic do not show any noteworthy change for 1936. Passenger receipts declined 0.4 % and goods receipts 0.6 %.

Denmark reports for the financial year 1935/36 an increase in passenger receipts, whilst goods receipts remain stationary. The increase in passenger receipts is explained by the electrification of the Copenhagen suburban lines, the opening of new services of motor omnibuses and a few increased rates. Goods traffic is affected by the restrictions of exports, especially as regards agricultural products. Production for home consumption increased in 1936.

Another remarkable traffic improvement took place in Sweden during 1936. Passenger receipts increased 5.3 % in the first half-year and goods receipts 6.3 %. The value of exports increased from 571 to 658 million crowns and the value of imports from 676 to 756 million crowns. The increase of the volume of

traffic is especially due to the production of ore in Lapland and to the iron industry.

In Finland the economic situation and traffic show a similar evolution to that of Sweden.

In Portugal, quantitative traffic shows a slight increase in 1936, whereas receipts have slightly decreased. A remarkable fact is that since 1929 the goods tonnage of the Portuguese Railways has only declined 8.1 % and goods receipts 7.1 %.

In Hungary, goods traffic increased in 1936 by 8 %. The purchasing power of this country, agricultural for the greater part, fell particularly during the crisis under the effect of the collapse of prices of agricultural produce. With a rise in these prices and good crops in 1934 and 1935, the general economic situation has again somewhat improved. This improvement is also attributed to the conclusion of advantageous commercial treaties.

The situation in Yugoslavia, where four fifths of the population live on agriculture, is analogous. Timber supplies the State Railways with 25 % of the total goods traffic. In 1934 and 1935 the situation improved somewhat, and then the sanctions against Italy caused another decline. It is for the same reason that the 1936 goods traffic is slightly lower than that of the previous year, whilst passenger traffic shows an increase.

Increased traffic is also to be noted for 1936 in Czechoslovakia, where the coal and iron industries revived.

IV. — Railway evolution from the standpoint of financial results and operation.

Operating receipts.

(See Table 9).

Up till 1933, operating receipts show a persistent tendency to decline. The greatest decline is found on the German and Polish State Railways, whose operating receipts fell by nearly half during

the short period from 1929 to 1933, and then on the Italian State Railways, the Austrian Federal Railways, the Hungarian State Railways, the Czechoslovak State Railways, the Belgian National Railways Co. and the Netherlands Railways where the financial loss varied between 30 % and 40 %. With the 1934-1935 increase in passenger receipts and goods receipts, there was a corresponding appreciable increase in operating receipts on most systems, notably on the German State, Swedish State and Danish State Railways. On the contrary, the persistent drop in traffic and receipts on the French main-line Railways, Netherlands Railways and Swiss Federal Railways caused a continuation of unfavourable operating results.

Operating expenses.

(See Table 10).

Whereas the general depression and traffic crisis caused an immediate and lasting fall of operating receipts, the operating expenses still continued to rise on several Systems or else it was not possible to restrict them except to a moderate extent. It was only since 1930 that

the Railways succeeded in effecting appreciable reductions in operating expenses and thus obtaining a more acceptable proportion between expenses and the reduced receipts. In the last two years covered by this report, a fresh rise in operating expenses can be noticed on a whole series of Railways notably on the German State, Swedish State, Danish State Railways and the British main-line Railways. It should be noted that on almost all the Systems who were able to record in the last few years a rise in traffic and an increase in operating receipts, the operating expenses show at the same time a rising tendency, whereas the other Administrations, whose receipts continued to fall, found themselves obliged to further reduce their operating expenses by prolonged and efficacious economies.

The experimental fact that in railway operation, when traffic lessens, operating expenses cannot be cut to the extent operating receipts have decreased, appears particularly clearly in the following comparison of the proportional decline, from 1929 to 1935, of operating receipts and expenses :

Proportional decline of operating receipts and expenses from 1929 to 1935.

—	Operating receipts. %	Operating expenses. %
Deutsche Reichsbahn	— 33.0	— 23.6
French main-line Rys.	— 36.9	— 14.5
Italian State Rys. (1)	— 42.1	— 29.1
Austrian Federal Rys.	— 37.9	— 31.5
Swiss Federal Rys.	— 23.9	— 14.3
Belgian National Rys. Co.	— 37.6	— 30.4
Netherlands Rys.	— 44.1	— 26.8
British main-line Rys.	— 16.2	— 14.2
Danish State Rys.	— 5.6	— 0.6
Swedish State Rys.	— 6.8	— 0.01
Norwegian State Rys.	— 12.2	— 8.5
Spanish main-line Rys. (1)	— 14.0	— 0.1
Hungarian State Rys.	— 34.5	— 13.8
Czechoslovak State Rys.	— 33.1	— 21.1
Polish State Rys.	— 44.1	— 46.7
Jugoslav State Rys.	— 23.2	— 26.7

(1) 1929-1934.

Operating surpluses

(See Table 11).

The more and more unfavourable evolution, since the beginning of the crisis, of operating receipts and expenses brought about a large decline of operating surpluses on all railways. From 1930 onwards the Danish State, the Norwegian State, the Czechoslovak State and the Yugoslav State Railways were no longer able to cover their operating expenses with their operating receipts. In 1933, most of the Administrations which we mention, and in particular the German State Railways, the French main-line Railways, the Italian State and Czechoslovak State Railways closed their operating accounts with a more or less important deficit. During the years 1934 and 1935 the financial situation of most of the Systems again improved. In those two years the English main-line Railways, the Swedish State and Polish State Railways were able to record higher surpluses; on the German State and Yugoslav State Railways and also, in 1935, on the Belgian Railways, the former deficits gave place to surpluses. Other Administrations such as the Austrian Federal Railways, the Czechoslovak State, the Danish State and Norwegian State Railways were able to show smaller deficits for those two years. Few of the railways suffered a further financial decline. Among them are the Netherlands Railways and the Swiss Federal Railways whose operating accounts for the financial year 1935 showed a much smaller surplus than that of the previous year, whereas the French main-line Systems, which had been able to show an operating surplus for 1934, reported a considerable deficit for 1935.

Operating coefficients.

(See Table 12).

When comparing for a given railway the total operating receipts, the total

operating expenses and the relation between these two sums (operating coefficient), it should not be forgotten that the method of drawing up the operating accounts and apportioning the expenses between the operating account and the capital account varies considerably from one system to another. Consequently the operating coefficients of the various Administrations cannot be directly compared one with another. On the other hand, the evolution of the operating coefficient of one and the same railway in several consecutive years gives an idea of the economic value of the operating.

It can be seen, generally speaking, that faced with the large decline in traffic and receipts during the first year of the crisis, none of the Railways succeeded in maintaining the ratio of operating receipts to expenses at the same level. In all instances receipts declined to a greater extent than expenses and consequently the operating coefficient rose. As soon as the decline in receipts stops, the railways generally succeed in still further reducing working expenses. If, later on, increased traffic causes an increase of operating expenses in actual figures, this rise rarely exceeds that of receipts and the operating coefficient usually continues to improve.

As regards the compression of operating expenses achieved by the various Administrations since 1929, it should be pointed out that several Railways had already made extensive savings before the crisis, which naturally restricted the possibility of effecting further economies. It should also be remembered that certain Railway Managements were obliged to make a greater financial effort during the crisis period in the interests of the national economic position and above all to combat unemployment, an effort which also exerts an influence on the ratio of operating receipts to operating expenses.

General budgetary surplus or deficit.

	1929	1934	1935
	In millions of the respective currencies.		
Deutsche Reichsbahn	+ 121.8	— 115.7	+ 17.4
French main-line Rys.	+ 320.6	— 3 570.2	— 4 011.8
Italian State Rys.	+ 600.9	— 219.0	—
Austrian Federal Rys.	+ 0.4	— 72.7	— 69.4
Swiss Federal Rys.	+ 15.0	— 43.0	— 58.7
Belgian National Rys. Co.	+ 405.0	— 156.2	— 92.4
Netherlands Rys.	+ 2.0	— 30.8	— 28.0
Danish State Rys.	— 31.0	— 19.4	— 17.2
Swedish State Rys.	+ 17.4	— 2.4	+ 3.1
Norwegian State Rys.	+ 1.1	— 2.1	— 1.9
Portuguese Rys. Co.	+ 0.1	— 6.6	— 9.6
Royal Hungarian State Rys.	+ 3.8	— 54.7	— 63.9
Czechoslovak State Rys.	+ 140.0	— 686.0	— 565.0

In our 1935 report we explained at length that in various countries *State subsidies* are granted to railways or that deficits of the latter are entirely or partially covered by grants from the States' general budget.

The deficits appearing in the above table, shown by the railway budgets taken as a whole, had to be made good from current resources of the State in Italy, Austria, Holland, Denmark, Norway, Hungary and Czechoslovakia.

In Belgium the debit balance from past financial years, amounting to 220.3 million francs, was carried forward. In addition, the dividend, which is guaranteed by the State, on the Preference Shares which stand in the balance-sheet at 10 milliards could not be paid out of operating receipts, and the State had to bear it.

In Switzerland the deficit of the Profit and Loss Account has been carried forward up to the present and covered by loans. But as, in accordance with the law, the Confederation is responsible for all debts contracted on account of the Federal Railways, there was created in the 1936 Federal budget a special fund of 8 million francs for clearing up the situation of the Federal Railways. In addition, in the financial programme of the 31st January 1936, a further sum of 35.7 million francs was provided for the creation of a Railway Fund. These

amounts were not raised to facilitate the operation of the Federal railways during the crisis period or to combat motor competition, but to ensure the financial equilibrium of the Federal budget which had been upset by guaranteeing the debts of the Federal Railways.

Tables 13 and 14 give information as to the *evolution of distances travelled by passenger and goods trains*.

The fight against the ever keener competition of motor transport has necessitated in all countries, as we show further on, the general acceleration of all transport and the multiplication of passenger trains. It is especially for this latter reason that the Railways, in spite of the crisis, were practically not able to reduce the mileage of passenger trains; on the contrary, they have increased it. A reduction of running expenses was attempted by means of measures with which we deal in another chapter. A particularly large increase in passenger train mileage is noticed on the Swedish, Italian, Belgian and Czechoslovak Railways and, since a certain time, also on the German Railways.

In goods services, on the contrary, they were naturally able to better proportion the train mileage to the volume of traffic. Thus, the goods train mileages dropped fairly extensively during the first years of the crisis, whereas inversely the traffic improve-

ment that has occurred in certain instances since 1933 has brought about an increased mileage of goods trains although, it is true, it is still far from reaching on most Systems the 1929 level, as is the tonnage actually carried.

* * *

CHAPTER II.

Railways and motor-transport competition.

I. — Causes and evolution of the transport crisis.

1. The evolution of motor competition.

In previous reports there was a lengthy exposition of the sudden development of the motor transport industry during the post-war period, of the changes it caused in the structure of traffic and its effects on railways. In the present report we propose to discuss the subsequent evolution which took place after 1934.

The Railway Managements who have replied to our questionnaire state almost unanimously that motor transport has made further progress in the last few years. In Belgium its increase since 1929 is estimated at 43 %. In Italy a continual progression was noted until the economic sanctions were put into force; as a result of the special steps taken at that time, and to which we shall refer further on, motor transport declined subsequently. In Czechoslovakia, equally, legal steps taken caused a decline of motor competition. In Portugal, where the carriage of passengers by road was regulated by law from the 1st January 1934 onwards, it was also found that this legislation caused a relaxation of the competition, whilst, it is true, as regards goods transport, competition has become keener. In Hungary and Bulgaria a remarkable fact is that not only motor vehicles but also animal traction, which has been able to take ad-

vantage of the extension of the network of roads and of the progress achieved in the construction of vehicles, compete successfully with the railways.

An interesting evolution has taken place in French Morocco. The standard-gauge railway system in that country was only opened in 1923, progressing steadily until, in 1928, it reached the present-day stage. Motor vehicles thus preceded the railways in opening up that country. The consequence of the opening of railways was to force motor transportation to reduce its rates in districts which it served. When, as a result of the economic crisis, the total volume of traffic declined and the railways sought to protect their traffic by adaptation of rates, motor carriers applied to the authorities to protect them against railway competition.

As regards the question as to *whether the development of motor transport has been favoured or otherwise by the world wide economic crisis*, opinions are divided. But there is general agreement in stating that the business depression has caused a demand for cheap means of transport and that it has consequently favoured the development of motor transport. The Belgian Railways clearly state that the extension of motor transportation has not been hampered by the crisis. The same opinion is expressed by the Yugoslav and Bulgarian State Railways. On the other hand, the majority of the Railway Administrations are of the opinion that if there had been a better economic situation motor traffic would have developed, but would have caused less harm to railways than what has actually happened, owing to the coincidence of the general economic crisis and the rapid transition from one means of transport to another.

Hitherto, most of the Railways have not noticed any indications which would enable the conclusion to be drawn that going over from rail to road has reached its culminating point. This

change-over is still continuing in almost all countries. The Norwegian State Railways are the only ones who are of opinion that the exodus on their system is practically ended.

As regards passenger traffic, it is generally speaking private automobiles and occasional motor coach excursions organised from time to time by professional road carriers which have caused most harm to railways. As to regular road services, they are of secondary importance in countries where they are only allowed on condition that they cause no harm to public services already in existence, whereas in Belgium, Sweden, Finland, Portugal and Bulgaria competition from public road motor services does not appear to be negligible from the railways' point of view. In France, where public motor services are also very competitive, the Decree issued in April 1934 concerning the co-ordination of the means of transport forbade the creation of further public services by road.

In a few countries private automobiles do not appear so far to have competed much with railways; this is the case in Sweden, Finland, Yugoslavia, Bulgaria and Japan, where competition from professional road carriers — either regular or occasional services — is the preponderating element.

As regards goods traffic, competition feels the influence of legislative steps taken in numerous countries. Where such steps have not been taken so far, as for instance in Switzerland and Holland, it is noticed that private traffic expands above all constantly on short runs, whereas road contractors, although having a smaller fleet of vehicles at their disposal, are looking for the most profitable traffic and thus compete with railways over ever longer distances, consequently causing most harm to the latter.

In Belgium it is hoped that recent

legislation will not fail to check the exodus of goods traffic.

In Hungary the professional carriage of goods beyond local zones is the legal monopoly of the State Railways. Motor transport contractors are grouped into an association (Mateosz) with which the Railway Administration has concluded a working contract. The professional transport of goods is thus regulated in Hungary by co-operation between rail and road and placed under one central management; consequently it is not of much importance as regards competition. On the other hand, private traffic (Werkverkehr) is developing more and more and competition is on the increase.

In Czechoslovakia, legislation has also had the effect of temporarily stabilising the situation from a competitive standpoint. But the State Railway Administration is nevertheless of opinion that with improved economic conditions, motor transportation will develop again on an ever larger scale.

In Japan, where it is practically only over short distances that motor traffic has become of importance, professional road carriers are the only ones to act to a certain extent as competitors to the railways; but it is anticipated that in the future there will be a considerable development of private traffic (industrial and commercial undertakings).

The *distances* over which motor competition makes itself felt to the railways are ever growing in most countries, both for passenger and goods traffic. As regards the latter, this applies particularly to convoys of fully laden lorries. The increased use of heavy diesel lorries has hastened this evolution. In Italy convoys of diesel lorries can be seen which, in spite of the much lowered railway rates for long-distance traffic, run throughout the country from Northern Italy to the extreme South.

In Belgium it has been noticed that motor competition makes itself particularly felt over distances running up to

75 km. (47 miles). In spite of a general reduction of railway tariffs on the 20th January 1935, the rates for distances below 75 kilometres being appreciably lowered on this occasion, increased traffic has only been noticed over greater distances.

In consequence of legislative steps taken in Czechoslovakia the working radius of professionally owned lorries has decreased, whilst that of private industrial traffic has increased.

The Japanese Ministry of Railways made a thorough enquiry in 1930, as to the distances up to which goods are carried by road. It showed that this transportation works out as follows :

Up to 20 km. (12.4 miles) . .	33 %
From 20 to 50 km. (31 miles) . .	41 %
From 50 to 100 km. (62 miles) . .	19 %
From 100 to 150 km. (93 miles) . .	6 %
Over 150 km.	1 %

It will be seen clearly from these figures that Japanese motor traffic is only really of importance over short runs and is practically insignificant for very long distances. In any case, during the last few years transport over distances of 40 to 50 km. is more extensive than that on 30-km. runs. That is why the

Japanese State Railways are of opinion that the time has now come when legislative steps ought to be taken for co-ordinating rail and road traffic.

Motor transport rates, both passengers and goods, show in most countries a continual tendency to drop, unless they are fixed by law. An exception to this rule is found in Italy where a tax per tonne-kilometre was imposed on and after the 1st January 1936 on goods carried by motor lorry. Together with the rise in the price of petrol due to the sanctions, this law has had the effect of almost doubling the prices for transport by motor lorry.

In Sweden the consequence of the improvement in the economic situation has been an increased demand for transport which, in its turn, has naturally caused a certain rise of the rates.

As regards the *evolution of vehicles from a constructional standpoint*, it appears that as regards private vehicles, small and light cars are becoming more popular, whereas public carriers of passengers and goods are using ever larger and larger vehicles. In Belgium this tendency is noticed especially as regards vehicles for transport in common, as the following table shows :

	1929	1934	Increase or decrease.
Light motor coaches . .	713	259	— 63 %
Heavy motor coaches . .	593	1 426	+ 142 %
Light lorries	40 250	55 246	+ 37 %
Heavy lorries	9 611	16 182	+ 68 %

In Hungary, where professional goods transport is placed under a single central authority, an attempt is being made to standardise a three-ton type.

Unlike what is happening on the railways, the types of undertaking which predominate in the motor transport industry are the small and very small firms. This dissemination has already on many occasions rendered inoperative attempts made to bring about, by mutual consent, co-operation between rail and road because one could never find,

among motor carriers, a contracting party qualified to make agreements in the name of the whole industry. Apart from a few agreements imposed by law, this situation has not changed much during the last few years. It is true that all the countries report that sometimes (mostly to consolidate the position of the undertakings) occasional agreements are concluded; but hitherto a systematic development on these lines has nowhere been successful on the basis of free agreements.

In Germany contractors holding a licence to carry goods over long distances have been grouped by law into an association having a rigid organisation and called « Reichs-Kraftwagen-Betriebsverband » (R. K. B.).

In Austria there exist in all branches of national activity associations that are made obligatory by law, and whose task is to safeguard professional interests. In Finland motor transport contractors form an association of motor vehicle owners. But in all these associations the various contractors retain their economic independence.

Centralisation is carried much further in the case of the Hungarian compulsory association called « Mateosz », in which each contractor must adhere rigorously to a common method of operation under a central management, which implies abandoning a large part of his economic independence.

In Portugal (1934) and in Bulgaria (1935) laws regulating public passenger services restrict the granting of licences to certain conditions which many of the former small contractors could not fulfil. The result has been a certain number of amalgamations in these two countries.

2. Effects of motor competition on the economic situation of railways.

It is undeniable and undenied that motor vehicles have captured a more or less considerable amount of traffic from the railways in all countries. The harmful effects of this competition on the financial situation of railways have made themselves felt the more that road motor vehicles extend their runs to longer distances and the average distance of rail transport is shorter. Owing to the amount of capital invested in railways and to the overhead charges which hamper operation, any decline in traffic necessarily entails a poorer use of the

operating plant required for handling the total traffic, and which cannot be reduced. As the high proportion of fixed charges does not allow operating expenses to be reduced proportionally to each traffic decline, the average cost per unit of production must necessarily rise as the use of the available plant decreases. The financial yield could therefore only have been maintained by means of a general increase of the rates. Now it was not possible to act on these lines owing to motor competition with its lower rates, and on another hand also owing to the general movement of prices which rendered merchandise more sensitive to transport charges. On the contrary, rates had to be lowered, either to prevent the divergence between the general evolution of goods prices and railway rates becoming too wide or to maintain, in each particular case, the fight against competitors with their cut rates. Under these circumstances the financial position of the railways could but become worse from two points of view. Not only did the efficiency decline proportionally to the declining use, but in addition receipts suffered a still greater setback than the traffic carried.

An exact determination of the loss in receipts due to motor competition is doubtless nowhere possible. In all countries discussions are waged in both camps as to the question as to what extent decline of railway traffic has been caused by the crisis and to what extent it is due to motor competition. In addition, it should be pointed out that the loss of railway receipts does not only depend on the quantities of traffic lost but also to the lower rates enforced by competition. On the other hand, it should be borne in mind that the automobile industry and road transport are new branches of the economic system by which railway traffic has benefited to a certain extent. As long as careful statistical censuses are not made concerning the nature and volume of road traf-

fic (see further on), one can only rely on mere estimates as to reciprocal effects between rail and road traffic.

Nevertheless, we have at our disposal certain reference points enabling us to make these estimates and railways make

use of them to determine the probable amount of receipts taken away from them by motor transport. In reply to enquiries we made in this respect, the Railway Administrations gave the following information :

Annual estimated losses of railway receipts caused by road competition.

	Passengers.		Goods.	
	Millions of the currency of each country.	Percentage of receipts.	Millions of the currency of each country.	Percentage of receipts.
Deutsche Reichsbahn	350	36	300	13
French main-line Rys.	—	—	2 000	29
Austrian Federal Rys.	15	11	54	19
Swiss Federal Rys.	15 to 20	12 to 16	40 to 50	24 to 30
Belgian National Rys. Co.	128	17	170	12
Netherlands railways	—	abt. 30	—	abt. 30
Swedish State Rys.	3	4	12	11
Norwegian State Rys.	11	40	5	15
Czechoslovak State Rys.	—	—	200	10
Bulgarian State Rys.	52	14	46	6
Japanese State Rys.	11.4	4	—	—

The German State, the Norwegian State and Bulgarian State Railways estimate the loss of passenger receipts in absolute value at a higher figure than that of goods receipts. In percentage of receipts the estimate of the Belgian National Railways Co. also shows a heavier loss for passenger receipts. The greatest losses of goods receipts are reported by the French, Dutch and Swiss railways. It might be concluded from this that automobile competition is favoured by

the crisis, which has lasted longest in these countries.

As regards *passenger traffic*, railways have suffered their chief loss owing to the fact that it is above all the wealthier passengers who have deserted the rail for private automobiles. On another hand, the general drop of incomes and the increased comfort of the cheaper-class carriages have tended to make other passengers travel in a lower class. The following table shows the evolution of this movement :

Number of passengers in the various classes.

(Millions.)

Railways.	1929			1935		
	1st cl.	2nd cl.	3rd cl.	1st cl.	2nd cl.	3rd cl.
Deutsche Reichsbahn	0.6	140.2	1 839.5	0.2	72.2	1 416.3
French main-line Rys. . . .	21.8	110.2	650.0	11.6	83.1	487.0
Italian State Rys. (1929/34) .	2.4	11.9	96.8	1.5	9.4	97.9
Austrian Federal Rys. . . .	0.15	2.1	102.7	0.06	0.58	53.8
Swiss Federal Rys.	0.36	6.06	120.1	0.10	3.95	105.8
Belgian National Rys. Co. . .	1.29	20.06	221.7	0.36	11.46	168.0
Prince-Henri Rys. (Luxem- burg)	0.01	0.23	5.36	0.008	0.16	4.05
Netherlands Rys.	1.14	7.7	49.9	0.36	3.41	42.2
Danish State Rys.		1.49	29.5		0.80	43.7
Swedish State Rys.	0.022	0.77	29.5	0.014	0.69	39.0
Norwegian State Rys. . . .	0.0055	0.16	17.6	0.0039	0.15	17.4
Finnish State Rys.	0.0044	1.58	21.4	0.0026	0.73	18.2
Hungarian State Rys. . . .	0.33	14.02	79.2	0.019	5.30	55.1
Czechoslovak State Rys. . .	0.076	3.89	267.0	0.013	1.71	199.4
Jugoslav State Rys.	0.049	1.32	46.8	0.019	0.71	37.5
Bulgarian State Rys.	0.0097	0.198	10.22	0.0039	0.107	7.62
Japanese Govt. Rys.	0.062	12.21	850.7	0.057	7.45	977.5

The average receipts per passenger in the years 1929 and 1935 work out as follows :

Average receipts per passenger

(In the currencies of the respective countries.)

	1929	1935
Deutsche Reichsbahn	0.69	0.65
French main-line Rys.	4.08	4.63
Italian State Rys. (1929/34)	11.97	9.64
Austrian Federal Rys.	2.09	2.53
Swiss Federal Rys.	1.23	1.15
Belgian National Rys. Co.	3.46	4.11
Prince-Henri Rys., Luxemburg	1.39	1.55
Netherlands Rys.	1.04	0.83
Danish State Rys.	1.57	1.20
Swedish State Rys.	1.91	1.61
Norwegian State Rys.	1.64	1.54
Finnish State Rys.	11.05	10.43
Hungarian State Rys.	1.12	1.04
Czechoslovak State Rys.	3.69	3.60
Jugoslav State Rys.	16.8	14.6
Bulgarian State Rys.	57.41	36.0
Japanese Govt. Rys.	0.28	0.28

It will be noticed that in most countries there is a decline of the average receipts per passenger, which is imputable on the one hand to the introduction of special reduced rates and on another hand to the above mentioned change-over from a higher to a lower class. But on the other hand an evolution in the opposite direction will be noted on the French, Belgian, Luxemburg and Austrian railways. In those countries railways are faced with competition from regular road services carrying passengers, which has doubtless had the consequence of passengers abandoning the rail for the road to an appreciable extent. In spite of the increase that has resulted in the average receipts per passenger, this evolution has had harmful consequences to the railways, seeing that the latter have to integrally maintain their services on runs affected by the exodus and have simply thus lost an accessory traffic which does not entail supplementary charges. As regards the French railways,

the additional fact should be borne in mind that taxes on passenger transport were reduced on and after 1st November 1933 from 32.5 % to 12 %. As fares remained unaltered this reduction of taxes meant increased receipts for the railways.

As to goods traffic, the carrying of complete car-loads over short distances was captured during the last few years to a large extent by motor lorries. As regards parcels, this has taken place to a much lesser extent and mostly on lines where traffic is intense, as the carrying of isolated parcels which cannot be grouped into complete car-loads is not very remunerative for lorries, who are therefore only too glad to leave them to the railways. But as the carrying of complete car-loads predominates from a quantitative standpoint, the average distance per ton of goods transported has increased for a few years past in most countries, as is shown by the following table :

Average distance over which goods are carried (km.).

—	1935	1934	1929
Deutsche Reichsbahn	158	159	158
French main-line Rys.	206.8	211.9	190.8
Italian State Rys.	—	233	198
Austrian Federal Rys.	139.5	139.2	144.7
Swiss Federal Rys.	121.40	113.24	115.82
Belgian National Rys. Co.	84	80	95
Danish State Rys.	119.9	113.7	96.0
Swedish State Rys.	168	154	96.2
(Lapp mineral traffic excluded).			
Norwegian State Rys.	103.5	101.2	144
Finnish State Rys.	160	157	169
Portuguese Rys. Co.	150.9	146.3	134.3
Hungarian State Rys.	135.0	135.8	120.4
Czechoslovak State Rys.	142.8	136.6	132.2
Jugoslav State Rys.	211	220	186
Bulgarian State Rys.	126.4	123.2	125.0
Japanese Govt. Rys.	172.9	172.3	162.9

The average transport distances have declined above all in Belgium, Austria and Finland. In the two former countries the reason is doubtless a decline of transit traffic which is of great quanti-

tative importance and which travels over comparatively long distances.

The average receipts per ton of goods carried and per tonne-kilometre are shown in the following table :

Average goods receipts.

	Per metric ton of goods.			Per tonne-kilometre.		
	1935	1934	1929	1935	1934	1929
In 100ths. of the currency of the country concerned.						
Deutsche Reichsbahn	643	676	799	4.08	4.27	5.05
French main-line Rys. . . .	3 442	3 563	3 664	20.63	21.50	24.21
Italian State Rys.	—	3 497	4 434	—	17.2	24
Austrian Federal Rys. . . .	1 360	1 400	1 340	9.76	10.02	9.29
Swiss Federal Rys.	1 122	1 138	1 159	9.24	10.05	10.01
Belgian National Rys. Co. . .	2 369	2 546	2 596	29.1	31.8	27.3
Prince-Henri Ry. (Lux.) . .	608	627	624	42.6	43.2	43.8
Danish State Rys.	872	832	810	7.3	7.3	8.4
Swedish State Rys.	953	892	949	5.67	5.80	6.57
(Lapp mineral Ry. exclud.)						
Norwegian State Rys. . . .	690	708	746	6.6	6.9	7.7
Finnish State Rys.	461	444	516	2.87	2.84	3.06
Portuguese Rys. Co.	421.5	411.4	407.3	2.79	2.81	3.03
Hungarian State Rys. . . .	826	861	869	6.12	6.34	7.22
Czechoslovak State Rys. . .	4 745	4 716	4 698	33.23	34.52	35.53
Jugoslav State Rys.	13 479	13 804	10 757	64	63	58
Bulgarian State Rys. . . .	14 870	15 490	18 490	114.5	122.3	112.9
Japanese Govt. Rys.	278	278	279	1.61	1.62	1.71

The average receipts per ton of merchandise carried generally show a tendency to decline. Where they have increased in recent years the fact is to be attributed to the longer average carriage distance. On the other hand, average receipts per tonne-kilometre have declined on almost all railways. Lorries are largely responsible for this drop. If we consider that the decline of receipts per tonne-kilometre was accompanied during the first years of the crisis by a great reduction in the volume of traffic, we see clearly why the financial position of railways has necessarily become much worse. The increase in traffic which has taken place in certain cases for the past few years has not been able to exert any marked effect on this position because it was accompanied by a lower average revenue.

3. Necessity for statistical bases to effect efficacious co-ordination between rail and road.

We have already pointed out that

investigators will be restricted to mere hypotheses in order to determine reciprocal effects between rail and road traffic as long as the extent and nature of road transport are not defined by statistical data. The latter are necessary above all as regards goods traffic because the position in this respect is least clear and the items set forth in an economic and numerical form play a much more important part than in passenger traffic. All attempts to regulate the relationship between rail and road in a definite manner will have an uncertain aim as long as one is not able to judge their effects beforehand on the basis of an exact knowledge of all the kinds of traffic in question.

The eighth Congress of the International Chamber of Commerce, held in Paris from 24th to 29th June 1935, passed a resolution stating: « The statistics requested as regards transport by rail and road should be restricted to those that are indispensable in order to show how far service conditions adapt themselves

to the measures of co-ordination adopted and which give, in the interests of the general economic system, details as to the movement of such traffic. Statistics concerning transport should be drawn up in a uniform manner in all countries, owing to the increasing importance of international traffic and in order to enable comparisons to be made between the various countries. »

This resolution expresses, for the first time, a positive demand for drawing up statistics « which give details as to the movements of such traffic ». But as, hitherto, in most countries no statistics have been kept, neither occasional nor regular, as to the nature and extent or road transport, the above mentioned resolution has still nowhere been followed by positive measures. There is here clearly something lacking, to which the Governments of all countries ought to pay heed in the interests of an ordered development of traffic.

As a result of the law passed in Germany on the 1st October 1935 as to long-distance goods transport, statistics are drawn up as regards road transport which contain details as to the total distances covered and paid for, dimensions, etc., of the various vehicles. But as they do not include all private industrial traffic nor private transport over short distances, these statistics do not enable us to gain a general insight into goods transport by road as a whole.

In Hungary, where the professional

goods transport is monopolised and entrusted to a Central Association, statistics are kept as to the nature and tonnage of goods carried, but they do not include uncontrolled private traffic.

In Italy the road police take traffic censuses from time to time, but these censuses are restricted to determining vehicular traffic at given points. No particulars are demanded from contractors themselves.

The first complete enquiry as to the volume of goods carried by road was made on and after the 15th June 1936 in Switzerland. It is obligatory to declare all goods carried more than 10 km. (6.2 miles) by road. For each consignment particulars have to be given on special printed forms: date, description of the goods or animals carried, weight or number of things carried, origin and destinations. These statistics will, finally, supply reliable data for regulating competition between rail and road. When the present report was drawn up, results of the statistics for July and August 1936 were known. We will analyse them briefly in the sense of the present report.

The total quantity of goods and animals carried during those two months a distance of over 10 km. by road is as follows:

543 737 metric tons of merchandise;
712 442 hectolitres of liquids;
94 485 animals,

subdivided as follows:

	Professional carriers.	Private traffic.
Merchandise (metric tons)	206 274	337 463
percentage	38	62
Liquids (hectolitres)	93 244	619 198
percentage	13	87
Animals	45 943	48 542
percentage	49	51

The total traffic was subdivided, according to the various distances, as follows:

	Goods (metr. t.).	%	Liquids (hl.).	%
From 10 to 30 km. (6.2 to 18.6 miles) . .	258 677	47.6	388 155	54.5
From 30 to 50 km. (18.6 to 31 miles) . .	100 797	18.5	147 392	20.7
From 50 to 100 km. (31 to 62 miles) . .	118 949	21.9	125 083	17.6
From 100 to 250 km. (62 to 155 miles) . .	62 971	11.6	47 743	6.7
Over 250 km.	2 284	0.4	4 034	0.6

	Animals (heads).	%
From 10 to 30 km. (6.2 to 18.6 miles) . .	31 360	33.2
From 30 to 50 km. (18.6 to 31 miles) . .	22 130	23.4
From 50 to 100 km. (31 to 62 miles) . .	26 478	28.0
From 100 to 250 km. (62 to 155 miles) . .	14 517	15.4
Over 250 km.	...	...

Traffic worked by professional carriers was as follows, as regards distances :

	Goods (metr. t.).	%	Liquids (hl.).	%
From 10 to 30 km. (6.2 to 18.6 miles) . .	72 553	35.2	29 930	32.1
From 30 to 50 km. (18.6 to 31 miles) . .	31 005	15.0	16 184	17.4
From 50 to 100 km. (31 to 62 miles) . .	54 752	26.5	22 438	24.1
From 100 to 250 km. (62 to 155 miles) . .	45 935	22.3	21 486	23.0
Over 250 km.	2 028	0.9	3 206	3.5

Private industrial traffic over the various distances was as follows :

	Goods (metr. t.).	%	Liquids (hl.).	%
From 10 to 30 km. (6.2 to 18.6 miles) . .	186 124	55.2	358 225	58.0
From 30 to 50 km. (18.6 to 31 miles) . .	69 792	20.7	131 208	21.2
From 50 to 100 km. (31 to 62 miles) . .	64 197	19.0	102 645	16.6
From 100 to 250 km. (62 to 155 miles) . .	17 036	5.0	26 257	4.2
Over 250 km.	256	0.1	828	0.1

Within these various distance zones, the total traffic was divided as follows in professional traffic and private traffic.

(a) Tonnes of merchandise :

	Professional carriers. %	Private traffic. %	Total. %
From 10 to 30 km. (6.2 to 18.6 miles) . .	25	75	100
From 30 to 50 km. (18.6 to 31 miles) . .	31	69	100
From 50 to 100 km. (31 to 62 miles) . .	46	54	100
From 100 to 250 km. (62 to 155 miles) . .	73	27	100
Over 250 km.	88	12	100

(b) Hectolitres of liquids :

From 10 to 30 km. (6.2 to 18.6 miles) . .	8	92	100
From 30 to 50 km. (18.6 to 31 miles) . .	11	89	100
From 50 to 100 km. (31 to 62 miles) . .	18	82	100
From 100 to 250 km. (62 to 155 miles) . .	45	55	100
Over 250 km.	80	20	100

Summarised briefly, the results shown by the above tables are as follows :
65 to 70 % of all road transport is carried over distances under 50 km. (31 miles); the proportion of traffic carried over less than 100 km. (62 miles)

is nearly 90 % and the limit of 100 km. is only exceeded by about 10 %. The *average distance of all road transport* ranges from 45 to 50 km. (28 to 31 miles).

As regards *traffic worked by professional carriers*, about 50 % of all transport is over distances under 50 km.; a little over 75 % remains below the 100 km. level, whilst this distance is only exceeded by a little under 25 %. The *average distance of traffic* worked by professional carriers is from 65 to 70 km. (40.4 to 34.5 miles).

More than half of *private transport* (commercial and industrial firms) is carried less than 30 km. and about 75 % of it less than 50 km. About 95 % of all private transport is over distances that do not exceed 50 km. The average transport distance ranges from 40 to 45 km. (25 to 28 miles).

Out of all transport under 30 km. about 75 % is by private lorries and about 25 % by professional carriers. The total quantity of goods carried up to distances of 50 km. is divided as follows: 70 % private traffic and 30 % worked by professional carriers. On runs of 50 to 100 km. private traffic still prevails, with 55 %, professional carriers only sharing 45 %. But on distances of over 100 km. professional carriers take by far the greater share: about 75 %.

Statistics for September 1936 confirm this proportion.

As regards competition between rail and road, the following general conclusions may be deduced from the above proportional figures:

About half the private traffic is not of much importance from a competitive standpoint, since it is carried over distances of less than 30 km. (But for the lines of private railways in Switzerland who often operate very-short distance services, this motor traffic is nevertheless a source of competition which has to be taken into consideration.)

Another quarter of private traffic is carried over distances of 30 to 50 km. and thus competes fairly keenly with the Federal Railways. On the other hand traffic of a very competitive kind, and which is largely taken away from the railways, consists of the remaining quarter of private traffic carried for distances over 50 km.

Traffic worked by professional carriers amounts to 35 % over distances of less than 30 km. In the next zone, 30 to 50 km., they work 15 % of this traffic, mostly in competition with railways. About a quarter of the traffic comes within the 50-100 km. zone and must be considered as having been taken away from the railways. Finally, the last quarter of the traffic, which is carried over distances exceeding 50 km., is not only of markedly competitive character but also deprives the railways of a large part of their remunerative traffic which they cannot dispense with if their financial balance is not to be upset.

In forming a judgment as to the distance-zones mentioned above, it must be remembered that, except in regions that are decidedly mountainous, Switzerland has a dense population with industrial and commercial centres scattered about the country. Consequently, the distances separating localities of a certain importance are usually short and traffic centres are as a rule not further apart than 30 km. The railway system is extremely compact, especially if we take into account the fact that there are many private lines, and thus motor traffic on the roads runs necessarily, even over comparatively short distances, parallel to the railway lines and cause considerable competition to the latter.

Another interesting matter is the composition of road motor traffic from the standpoint of the products carried. The following table supplies information in this respect:

Composition of motor traffic from the standpoint of products carried.

	Traffic taken as a whole.		Traffic carried more than 50 km.	
	metr. tons.	%	metr. tons.	%
Wheat, flour	66 468.8	10.68	26 924.0	12.99
Fruit, vegetables	29 369.4	4.72	13 311.1	6.42
Wine, beer	30 104.9	4.84	8 467.2	4.08
Other foodstuffs	67 153.6	10.79	27 960.1	13.47
Other drinks	25 770.9	4.14	10 363.2	5.0
Fertilizers, offal, hides and leather	9 966.6	1.60	6 377.1	3.08
Seeds, plants, fodder	42 281.9	6.79	15 324.9	7.39
Building and other timber	24 780.4	3.98	9 656.5	4.66
New furniture	2 640.9	0.43	1 300.8	0.63
Wooden articles of all kinds	17 552.7	2.82	5 001.0	2.41
Paper and drawing materials	10 800.2	1.74	6 240.3	3.01
Textiles, clothing	8 610.6	1.38	3 888.1	1.88
Gravel, sand; crude or dressed stone	88 317.1	14.19	6 391.3	3.08
Cement	28 799.5	4.63	11 024.5	5.38
Other mineral matters	38 012.7	6.11	7 172.6	3.46
Tiles, bricks	25 846.9	4.15	5 661.6	2.73
Other pottery and glassware	4 627.6	0.74	2 511.6	1.21
Metals	25 908.0	4.16	12 085.2	5.83
Machinery, clockwork	5 243.4	0.84	2 413.8	1.16
Benzine, benzol	18 520.9	2.98	3 116.5	1.53
Crude petroleum	1 501.6	0.24	446.4	0.22
Drugs and chemical products	31 510.6	5.07	15 081.6	7.28
Removals	4 130.6	0.66	2 066.5	1.00
Other unspecified goods	3 406.6	0.55	1 373.1	0.66
Parcels	1 264.5	0.20	652.9	0.31

Among goods carried any distance, building materials, gravel, sand, stone and next cement, tiles and bricks take first place. It is not surprising that these low-priced goods in bulk exceed all others from the standpoint of weight. These are mostly consignments for building purposes, principally carried out in the short-distance zone over which motor lorries have taken the place of horse-drawn vehicles. The proportion of such products is much smaller over long distances; indeed, the part taken by gravel, sand and stone in the total volume of traffic carried more than 50 km. only amounts to 3.08 %, whereas over short distances this part rises to 14.19 %. But as the building trade employs a very large number of particu-

larly heavy motor vehicles, used to carry materials to or from building sites there is naturally a tendency to use them most intensely. That is why such vehicles are fairly often used for transport over greater distances, whilst selecting, it is true, those building materials that are of high value, particularly cement. That seems to be the reason why cement still takes an important place in transport carried more than 50 km. The proportion to which it is included in such transport is even higher than in transport as a whole, including short-distance traffic.

If we set aside the special conditions existing in the building trade, we find that *foodstuffs* transport easily takes first place. If long-distance traffic be considered separately, foodstuffs share

an even larger part than in transport over all distances. A similar fact is noticed as regards wheat and flour. In this instance it should be remembered that already in the times when animal traction existed, in the milling trade there was quite an active private traffic which is now handled by lorries. If transport of wheat and flour were quoted separately we should certainly find for long-distance traffic a large preponderance of flour because the latter, owing to its higher specific value, has to pay higher rates on the railways.

Apart from the products mentioned above, road traffic in general consists above all of seeds, plants, fodder (6.79 %), mineral matters exclusive of coal (6.11 %), fruit and vegetables (4.72 %), wine and beer (4.84 %), other beverages (4.14 %), metals (4.18 %), drugs and chemical products (5.07 %).

As regards traffic carried more than 50 km., we notice above all (apart from foodstuffs already mentioned wheat and flour) the following articles : drugs, chemical products, dyeing materials (7.28 %), seeds, plants, fodder (7.39 %), fruit and vegetables (6.42 %), wine, beer (4.08 %) and other beverages (5.0 %), metals (5.83 %), building and other timber (4.66 %).

These statistics supply clear proof in support of the statement oft repeated by the railways that it is above all high-priced products that have been captured by road transport, whilst low-priced bulk merchandise continues to be carried by rail. In cases where the latter have gone over in more or less large quantities to road transport there are special reasons, such as in the building trade or the milling trade or where rough timber is carried immediately after being hewn. But as regards the remainder we find that motor traffic only handles secondary quantities of raw materials of real importance to industry and trade such as coal, pig iron, raw cotton, as well as a large proportion of

potatoes, fertilizers, etc., whereas it is precisely these products which supply quantitatively the greater part of goods traffic. First place in motor transport, also especially in long distance traffic, is taken by foodstuffs and beverages of all kinds. In certain cases, such as vegetables, the technical advantages of lorries have played a decisive part. But on the other hand, it is a matter here of products of a comparatively high value, the consumption of which is not subject to much fluctuation, so that the whole foodstuff trade has been able to organise itself with a view to a fairly constant motor transport, which means a good utilisation of vehicles. A particularly typical example of a category of goods of high value which forms an exceptional proportion of motor traffic is supplied by chemical products, drugs and dyeing materials.

Parcels are only carried by lorries to a very small extent. In the whole of the traffic they only amount to 0.20 % and for long distance traffic alone to 0.31 %. On the Swiss Federal Railways the proportion of parcels amounts to 8.6 % of the total goods volume carried. As these figures show with marked clearness, motor transport captures almost solely car-load traffic, which is remunerative and enables the vehicles to be rationally used, whereas it leaves almost entirely to the railways the forwarding of individual parcels to be delivered to a host of consignees and thus necessitating intricate routes that overlap or intersect each other. Railways are obliged to keep going the expensive operating arrangements for this service, but lucrative carload transport is leaving them more and more.

Apart from Switzerland, *Japan* is the only country in which statistics have so far been kept as to the volume and nature of road traffic as a whole. In 1930, the Japanese Ministry of Railways compiled data which also show the compo-

sition of goods traffic by road according to distance-zones. A comparison of the Japanese and Swiss results is interesting :

Traffic carried :	Japan.	Switzerland.
Up to 20 km. (12.4 miles)	33 %	28 %
From 20 to 50 km. (12.4 to 31 miles) . . .	41 %	38 %
From 50 to 100 km. (31 to 62 miles) . . .	19 %	22 %
From 100 to 150 km. (62 to 93 miles) . . .	6 %	8 %
More than 150 km.	1 %	4 %

This comparative table shows that conditions are much more unfavourable for the Swiss Railways, especially if we stop to consider at the same time the much shorter distances over which transport is carried on their system. Whereas in Japan the whole motor transport in 1930 only amounted to 6.4 % of the tonnage carried by the Government Railways, the Swiss statistics for the two months known so far show a proportion of 29 % on the Federal Railways.

4. Guiding principles for co-ordination.

Previous reports already pointed out that the steps taken in various countries by the State to put a stop to the transport crisis had been pure attempts and that nowhere had a final and lasting solution been reached. The evolution that has since taken place has brought no new factors towards a solution of the problem, and thus there is to-day great uncertainty as to the direction which the principle of rail and road co-ordination should take. This uncertainty is imputable above all to the fact that in leading economic circles, and sometimes also in Governmental quarters, sufficient account is not taken of the nature and extent of the primordial questions that have to be settled.

During the first years in which road competition began to make railways uneasy, the latter, owing to the many legal obligations to which they are subjected, found themselves unable to react

by means suited to the new method of transport, which was not similarly hampered. Their first efforts tended towards obtaining freedom of action which was necessary if they were to efficaciously protect themselves against this new form of competition. But, on the one hand, relaxation of the various legal obligations imposed on railways met with greater difficulties than had been imagined at the beginning; on another hand, the railways became aware that motor transport was increasing to such an extent that, even with greater liberty of action, they would not be in a position to combat with their own means this new form of competition. Faced with an ever more and more unfavourable financial situation and the continual expansion of motor transport, steps have been taken in all countries to avoid a sudden aggravation of the situation; but in nearly all instances these steps have only been of a makeshift or tentative nature, and nothing definite and durable has been accomplished.

The railways have not ceased to stress very energetically the *unequal competitive conditions* under which the two methods of transport operate. From a financial standpoint it has been repeatedly pointed out that railways have themselves to face the outlay entailed for construction, maintenance and amortization of their permanent way, whereas motor vehicles use public roads and only contribute an insufficient share towards their construction and maintenance costs. But this argument necessarily

became less pertinent when railways, in order to continue operating, had to solicit financial help from the State (without mentioning the sometimes substantial sums of capital contributed without security by the public authorities for the construction of railways, nor the fact that in certain countries the State long ago took over the cost of construction and amortization), and when on another hand the various sources of revenue which States acquired from motor traffic went on increasing. The question as to which, and to what extent, of the two means of transport is favoured from the point of view of charges for construction and maintenance of its permanent way has been nowhere hitherto elucidated in a complete manner because, on the one hand, reliable information is lacking as to the amount of construction and maintenance expenses for public roads which expenses are sub-divided among the State, the provinces and parishes, and because on another hand, as far as railways are concerned, grants from States, former subsidies, losses due to the collapse of railway shares, refloating, etc., have created a very confused state of affairs.

But in reality this question has not the same importance attributed to it at the outset. Assuming that it were possible to bring about complete equality between the charges inherent to the permanent way used by the two means of transport, competitive conditions would still be far from being the same. Thus, the railways pointed out from the very beginning the difference in legal labour conditions, for the purpose of demanding, in view of this, a relaxation of the obligations hampering them; but when presenting their claims they neglected the fact that motor transport is by its nature an *individual traffic*, whilst the technical character of railways compels them to carry out a methodical organisation of their operation. The advertising and regularity of their services are con-

ditions that are not only imposed upon them by the State but which also arise from their technical nature.

For this reason it is erroneous on principle — and this has hitherto generally been disregarded — to look upon the question of co-ordination between rail and road from the standpoint of different conditions under which they compete. The technical nature of the two means of transport is so different that the conditions under which they compete cannot be rendered equal in a natural sense.

The proof having also been supplied in actual practice that the State cannot avoid its duty of intervening actively in one form or another, the question thus becomes: Does the interest of the community require that a public and regular transport service, such as is supplied by railway technical organisation, should subsist or is it admissible or even desirable that the task of ensuring transport should be left to unhampered private initiative, seeing that the technical possibility of this solution has been supplied by motor traffic?

If the reply to the second question were to be in the affirmative, the progressive liquidation and suppression of railways in existence would have to take place and the State would only have to intervene in the normal course of events because the refunding in a too short period of the enormous amounts of capital invested in railways could not possibly be borne by the economic system of the nation. In the end, the only railways that would continue to exist would be those who, freed from legal obligations, but burdened by initial charges entailed by the very technical nature of railways, would be in a position to compete with their own resources against unfettered private undertakings.

If, on the contrary, it is admitted that legal conditions under which railways operate at the present time are all to the public good and cannot be abolished

without harm to the latter, we are then faced with two solutions :

(a) Instead of remaining unfettered, road traffic must be so closely restricted by legislative and fiscal measures that it does not compromise the existence of public transport services operating like the railways. In this case one could :

(1) abolish public motor carriers as individual services and combine them organically with rail transport, which could best be carried out by creating a legal transport monopoly under the management of the railways;

(2) retain, in addition to private industrial traffic, professional motor carriers to the extent allowed by the necessity there is of maintaining public transport services going;

(b) If, on the contrary, the State considers it has reasons which forbid it to restrict, to any extent whatsoever, unfettered motor traffic, then it must come to the help, by means of grants out of public resources, of public transport services which public interests require to be maintained.

The principle on which must be based the choice between these solutions makes it necessary that a clear conception be formed as to the consequences which it will entail. Intervention by the higher authorities in the management of railways, or even the taking over of the latter by the State, had serious reasons. The economic signification of the *system of rates based on values*, as applied by the railways, is known. The publishing of railway rates and their uniform application on equal terms to all consignors procures for the public reliable bases for calculating expenses and for competition. The charging of the same rates on lines having heavy traffic and only light traffic helps decentralisation and the development of rural districts. A regular and reliable

service is also an essential condition to the existence of industry, trade and professions in localities situated far away. We have already mentioned the fact that the carriage of parcels to such places is still carried out to-day almost exclusively by the railways. We might add that reliability, rapidity and continuity of postal services depend mainly on railways. These few reminders will suffice to prove that European States, with their uniform and decentralised economic conditions, cannot afford to relinquish the *organisation of transport placed at the service of the community*. For it constitutes a *public service* which must either be maintained with the help of the public resources or sufficiently protected against individual private carriers for it to be able to exist by its own means.

It is within this scope that co-ordination of rail and road will have to be brought about in the future. In the following chapter we will explain what are the tendencies which are already perceptible in various countries in this respect. It is true that hitherto very few countries have set themselves a clear course as regards this point.

In this connection, an important question arises as to up to what extent existing railway lines can be advantageously replaced by road motor services. Unless it is a question of railway lines that cannot lay sufficient claim to exist from the standpoint of national utility, such a change-over of operation must of course not render the service less satisfactory. The following table shows that in recent years very modest steps have been taken towards a suppression of existing railway lines, whereas on another hand new railway lines are still being built to-day in several countries. This proves clearly that even on secondary lines road motor vehicles are only capable in comparatively rare cases of entirely replacing, at lower operating costs, transport by railway.

Lines which, in 1936, were being operated, or under construction or on which the service was suspended during the years 1929 to 1936.

—	Lines.		Lines abandoned in 1929/1936 km.
	operating km.	under construction km.	
(S) = standard gauge. (N) = narrow gauge.			
Deutsche Reichsbahn	54 332	103	7.77
French main-line Rys. (S)	42 211	1 032	163
Italian State (S)	16 307	455	219
(N)	778	129	33
Austrian Federal (S)	5 430	—	—
(N)	416	—	95.2 (*)
Swiss Federal (S)	2 941	—	—
(N)	72	—	12.6
Belgian Nat. Rys. Co.	7 453	—	—
Prince Henri (Lux.) (S)	181	—	—
(N)	12	—	—
Netherlands Railways	3 396	—	305
Danish State	2 513	—	26.62
Swedish State	7 526	174	—
Finnish State	5 501	408	—
Portuguese Rys. Co.	2 469	63	—
Hungarian State	7 818	—	13.7
Czechoslovak State (S)	11 114	135	37
(N)	300	—	—
Jugoslav State (S)	7 126	283	50.5
(N)	2 296	111	—
Bulgarian State (S)	2 794	47	—
(N)	420	69	—
Japanese Government	17 138	1 711	—

(*) Of which 55.7 km. for passenger traffic only.

The question of replacing railways by road motor services was studied very minutely and completely in Switzerland. In March 1935, the Swiss Federal Railways' Board of Management entrusted two well known specialists, Messrs. ZIPFEL, Director of the Saurer Motor Lorry Works at Arbon, and DECHEVRENS, President of the « Chambre syndicale de l'Industrie de l'Automobile », Geneva, to enquire as to on which lines of the Swiss Federal Railways it might be considered advantageous, from a technical and financial standpoint, to substitute a service of motor lorries for railway operation. In their report the experts came to the conclusion that the

replacing of railway lines on the Swiss Federal Railways would encounter serious difficulties, notably owing to large traffic fluctuations, not only seasonal but also due to transport of raw materials, and then also owing to the fact that the industries are spread all over the country and because factories requiring an important traffic of raw materials and of finished products are situated in purely rural districts.

At the same time the experts admitted that before a final judgement could be passed as to the situation, a verification of the findings of their enquiry by the Railway Management was indispensable. The following are the conclusions reach-

ed after a conscientious and contradictory enquiry :

1. Replacing railway trains by road motor services is only economical under certain conditions, viz. when it is a question of passenger trains handling a moderate traffic, as stable as possible, and which are dispensed from any accessory task such as transporting express goods, milk and other foodstuffs, animals, etc.

2. On a regular service railways are superior to motor services because the commercial speed of motor vehicles and their carrying capacity are much lower.

3. Replacing railway services by motor services would entail serious drawbacks such as the slowing down of transport, both of passengers and of all other kinds of traffic, with resultant serious losses of traffic to the Administration.

4. Motor services would imply a relaxation of the obligation to carry, whence considerable inconvenience to the districts concerned.

5. Motor services are as a rule more onerous than railway services. Among the lines included in the enquiry it would lead to a reduction of expenses only on the Fribourg-Payerne-Yverdon route. But the resultant drawbacks to the railway and its clients would more than outweigh this advantage.

6. The experts state that they chose for their enquiry lines on which a substitution of motor vehicles for the railway or for certain railway trains could most easily be effected. The enquiry showed that, even on such lines, the adoption of the new operating method would neither be practical nor economical.

II. — Legislative measures tending to overcome the transport crisis.

1. Railway legislation.

The materialization of the relaxation, initially requested by the railways, of

their legal obligations, encountered great difficulties everywhere. Furthermore, railway legislation has practically, for a number of years past, undergone no radical changes anywhere. One can discern in this fact a proof in support of the thesis that an abandonment of the transport policy, as at present practised by all States and which has the public well-being as its aim, would lead to far-reaching economic and social changes whose repercussions are everywhere considered as undesirable. Now, if one remains faithful to the traditional transport policy, it is essential that the most important items of railway legislation remain unaltered. It has, moreover, been ascertained that nowhere has an essential relaxation of the obligation to operate and to carry imposed on railways been undertaken. Now, it is above all these obligations which burden the railways particularly heavily in their competition with road motor traffic. If they are to be retained, the reason is that it is precisely the obligation to operate and carry which confers upon the railways that character of prevision and operating reliability which must exist in all parts of a country in the interest of a uniform economic evolution.

The most important changes have been made in the matter of tariffs. Importance continues to be attached to the preservation of tariffs according to values, based on general economic requirements; the tendency is even everywhere to protect it in case of need by equally imposing restrictive measures on motor vehicles. The obligation to publish rates has on principle been abolished nowhere, as it is clearly not desired to deprive the general public of this precious basis of calculation. On the contrary, the railways have more and more been allowed certain facilities to grant competitive rates, or reduced rates to important clients, who threatened to resort to road traffic, but it is generally understood that such favours shall also

be granted under similar circumstances to all consignors. In addition, in most instances the extent to which such reductions or rates can be allowed is restricted. By a decree issued on the 20th October 1935, the French Railways were authorised to conclude tariff agreements with certain consignors. The Swiss Federal Railways have generalised the practice of inserting in certain exceptionally low rates a clause stating that these rates are only applicable to consignors who hand to the railways all such goods enumerated in the rates lists.

In Germany the evolution was in the opposite direction. The conception that railways constitute a *public service* which must be managed on principles of common interest and not according to mercantile rules, viz. with a view to furthering private interests, has been sternly applied there. All rates laid down with a view to competition with road motor services have been repealed; but on the other hand professional road transport over long distances has been subjected to rates which closely approximate those of the Reichsbahn.

Moreover, the revision of numerous provisions of a secondary nature in railway legislation is proceeding in several countries. In Switzerland the preparation of a general revision for the purpose of adapting legislation to present circumstances has been entrusted to a special committee of experts whose work is already well advanced. But the proposals made do not comprise any revolutionary innovations.

Nor has the system of taxes to be paid by railways been altered as a whole. Where fiscal transport taxes exist, they have usually remained in force without any changes.

2. Motor vehicle legislation.

The tendency, explained above, to preserve to railways their characteristic of public services for the common welfare has had the result that legislation to prevent motor vehicles from causing excessive harm to railways is being set up in almost all countries.

(a) Police traffic regulations.

The legal provisions which, in the interest of public safety and maintenance of roads, impose upon road carriers certain restrictions have, as regards their actual nature, nothing to do with regulation of competition between rail and road. But as the economic value of road transport, and consequently also its aptitude to compete with railways, depends to a large extent upon police traffic regulations, it is advisable to review them briefly in the present report.

(aa) Speed restrictions.

In most countries there is no speed limit for light motor vehicles. The maximum speed is as a rule laid down in Norway and in Algeria at 60 km. (37.3 miles) an hour, in French Morocco at 75 km. (46.6 miles), in Finland at 70 km. (43.5 miles), and in Japan at only 50 km. (31 miles). In Austria and Czechoslovakia the speed within built-up areas must not exceed 35 km. (21.7 miles) an hour; in Finland the corresponding limit is 45 km. (28 miles) an hour.

For *heavy vehicles* there is no speed limit in Germany and Holland. In other countries the following regulations exist:

France. — The maximum speed varies according to the total weight of vehicles as follows :

Total weight.	Pneumatic tyres.	Solid tyres.
From 3 to 6 tons . . .	65 km. (40.4 miles).	30 km. (18.6 miles).
From 6 to 10 tons . . .	55 km. (34.2 miles).	25 km. (15.5 miles).
Over 10 tons . . .	45 km. (28 miles).	20 km. (12.4 miles).

Vehicles whose width exceeds 2.20 m. are not allowed to run at a speed over 50 km. (31 miles) an hour.

Austria. — Vehicles not fitted with pneumatic tyres or vehicles hauling trailers must not exceed 30 km. (18.6 miles) per hour (20 km. = 12.4 miles within built-up areas).

Switzerland.

	Between localities.	In localities.	Vehicles not fitted with pneumatic tyres.
Lorries	45 km. (28 miles).	30 km. (18.6 miles).	20 km. (12.4 miles).
Tractors	40 km. (25 miles).	25 km. (15.5 miles).	20 km. (12.4 miles).
Trains of trailers . . .	35 km. (21.7 miles).	25 km. (15.5 miles).	15 km. (9.3 miles).

Belgium. — As in France, the speed limits vary according to the total weight:

Total weight.	Motorbuses.	Lorries.
Between 3.5 and 5 tons . .	65 km. (40.4 miles).	60 km. (37.3 miles).
Between 5 and 8 tons . .	60 km. (37.3 miles).	50 km. (31 miles).
Between 8 and 12 tons . .	50 km. (31 miles).	40 km. (25 miles).
Over 12 tons . .	40 km. (25 miles).	30 km. (18.6 miles).

Sweden. — Here also, speed limits vary according to weight (motorbuses and lorries).

Total weight.	Between localities.	Within localities.
Up to 3.6 tons . .	40 km. (25 miles).	35 km. (21.7 miles).
Between 3.6 and 6 tons . .	35 km. (21.7 miles).	30 km. (18.6 miles).
Over 6 tons . .	30 km. (18.6 miles).	25 km. (15.5 miles).

When trailers are hauled, the speed must in all cases be reduced by 5 km. (3.1 miles) per hour.

Finland. — For lorries whose total weight does not exceed 3.6 tons the maximum speed is 30 km. (18.6 miles) and when over 3.6 tons, it is 25 km. (15.5 miles).

Czechoslovakia. — The speed of motorbuses and lorries must not exceed 50 km. (31 miles) per hour; for motorbuses running on regular services exceptions may be authorized.

Japan : The maximum speed is fixed at 35 km. (21.7 miles) per hour for heavy vehicles and at 25 km. (15.5 miles) for vehicles hauling trailers. Higher speeds are authorised on certain specified routes.

(bb) **Weight restrictions.**

There is no weight limit in Austria, Holland, Czechoslovakia, Yugoslavia and Bulgaria.

In Germany the weight on any one axle must not exceed 7.5 tons and on the others 5.5 tons.

In France the weight of any single vehicle is restricted to 19 tons, and that of its train of trailers to 21 tons. For producer-gas or accumulator-driven vehicles, one additional ton is allowed.

In Algeria the maximum weight allowed is 15 tons.

In Switzerland the total weight of any single vehicle (including tractors) must not exceed 15 tons. For special vehicles and vehicles having three axles 13 tons is allowed, and for trains of lorries 16 tons.

In Belgium each vehicle carries a plate on which is inscribed the maximum weight allowed by the authorities according to the kind of tyres, their width and the diameter of the wheel. In Hungary, also, the maximum load-weight is affixed to any vehicle when it is licensed to run.

In Denmark the total weight of a road vehicle must not exceed 8 tons.

(b) Police regulations concerning labour.

As regards the question with which we are dealing, legal prescriptions concerning the work to be done by motor vehicle staff exist in most countries. They are sometimes contained in the general legislation concerned; sometimes special regulations have been drawn up for staff of transport undertakings and in particular for motor vehicle drivers. In Denmark and Finland there are no regulations regarding labour conditions, hours of service, nor wages. In Holland and Norway only the hours of duty on public motor lines have been regulated. In Austria, Hungary and Yugoslavia general legal provisions are applied to working conditions and hours of service.

In Germany the working period must not exceed 132 hours a fortnight, including time taken for waiting and preparation. Each working period must be interrupted with time off, which, according to the service, lasts from one to five hours and which must be *followed* by an unbroken rest of 8 to 10 hours according to length of duty.

No driver is allowed to be at the wheel for more than 10 hours when on actual duty.

During each fortnight every employee has a right to 2 days off of at least 24 hours each. In addition, for each nine months service he is granted 6 to 15 days holiday, according to the length of duty he has performed.

When employees are on long-distance runs they receive, in addition to their pay, certain travelling expenses.

In France, Algeria and Morocco the 8-hour day is expressly decreed for staff on motor vehicles. In France permanent exceptions are made as regards overtime for chauffeurs. In all cases the rest-time in between two days work must be 12 hours. General labour conditions for motor vehicle staffs are being drawn up on the basis of the decree of the 30th

October 1935. In Algeria extensive collective (union) contracts exist which also provide for minimum wages and a restriction of daily runs.

In Italy, labour conditions are regulated by the corporative organisation of the State, by means of collective contracts made between the employers' and workers' syndicates.

In Switzerland the week's work is fixed at 54 hours (for periods of a fortnight) by a special decree based on the law concerning motor vehicles. Heavy motor lorries may not be driven at night time.

In Belgium it has also been decided to apply the 8-hour law. For continuous working hours and time off in between there are special regulations. In addition, by virtue of the law a *joint committee* (employers and employees) has been set up which expresses its opinion on all matters concerning the labour conditions of workers on motor vehicles.

In Czechoslovakia, also, a governmental decree has enforced the regulations concerning the 8-hour day and the 48-hour week, and has specially regulated the periods of work and time off for the staff of road transport undertakings. Once a week a continuous rest of 32 hours must be granted.

In Bulgaria, where the 8-hour day is also obligatory, drivers must legally be members of a professional association which sees that the legal labour conditions are adhered to. A new law respecting obligatory collective contracts will shortly be put into force.

For staff on motor vehicles, Japan is also planning the introduction of the 8-hour day, with an obligation to grant two days off duty per month.

But in addition to the prescriptions mentioned above, these police regulations may also contain other provisions concerning the general conditions of competition between the various undertakings. Although these prescriptions are in appearance very similar to those regulating competition between

rail and road, their object is restricted to inner professional protection. Thus in Austria, in accordance with the terms of the law respecting professions, occasional professional transport of passengers is subject to concessions. In Jugoslavia all public road services are subject by law to concessions and are obliged to adhere to certain rates. There, relations between rail and road are solely regulated by the application of the general law on professions.

Owing to the extremely keen competition of public road carriers, not only with railways but also with one another, and also owing to the unchecked lowering of rates, protective laws of this nature have been demanded by road carriers themselves. Thus the Association of Swiss lorry owners have demanded in a petition to the Federal Council that the professional road transport be made subject to a licence and that general rates be enforced. It is true that these circles, for obvious reasons, do not wish to hear of any further restrictions on motor vehicles for the purpose of co-ordinating rail and road transport.

(c) Legislation concerning concessions.

The promulgation of laws respecting concessions for road carriers can be observed in an ever increasing number of countries. Those that were explained in detail in previous reports will be briefly summarised below for the purpose of giving a general view without omissions, whilst laws recently promulgated will be discussed somewhat more fully. In conformity with the method previously adopted, we will briefly review the various countries.

Germany : Passenger transport carried out professionally is regulated by the Road Passenger Act dated the 4th December 1934. Both occasional and regular services are subject to authorisation. In both cases proof of the necessity for such a service has to be given, a proof which in the first case need not be supplied for each particular trip but as

regards the undertaking to be licensed. Authority for occasional transport may be restricted to given districts. Where a regular line is worked the rates have to be approved by the administrative authorities. Once they are decreed they are binding upon everybody. The German State Railways and the German Postal Authorities need not ask for an authorization.

For goods traffic the provisional decree dated the 6th October 1931 was replaced by a law passed on the 26th June 1935 concerning the professional transport of goods over long distances. Permits have to be obtained by contractors carrying goods to points over 50 km. (31 miles) distant from the place where the lorry is usually stationed. Contrary to the former provisional ordinance this law makes the obtention of an authorization subject to supplying proof of the necessity for such a service. On expiry of a certain transitional period licensed contractors can only carry goods over long distances, in order that their whole activity may be controlled in a complete and continuous manner.

According to the terms of the ordinance dated the 28th December 1936, the granting or transfer of licences to carry goods over long distances by motor vehicles is subject to payment of fixed taxes as follows :

For carrying goods over long distances throughout Germany :

For the first vehicle.	50 RM.
For each additional vehicle belonging to the same contractor	20 RM.

Although observance of the regulations contained in the provisional decree concerning rates is difficult to control and even impossible to obtain, the new law maintains on principle an obligation to draw up rates. In order to facilitate the carrying out of this regulation, contractors were grouped obligatorily into an Association of motor carriers which in the first instance controls their operations. Rates are fixed by the Association in agreement with the Reichs-

bahn. The Association undertakes, on behalf of the contractors, to collect transport taxes.

By means of the rigid organisation of this Association of motor carriers, professional carriers of goods over long distances by road become partners on an equal footing with the Reichsbahn. The convention mentioned in the first main report, between the Reichsbahn and the Association, and which would have subordinated motor traffic to the railways, did not come to fruition. The two means of transport are « productive competitors » (consequently, rivalry of prices is excluded). From the legal point of view, motor traffic is organised in a uniform manner on the model of railway goods traffic.

Professional goods transport over short distances remains free on principle; the same applies to all industrial private traffic (Werkverkehr).

France.

A decree dated the 19th April 1934 made licences obligatory for all public motor transport of passengers and goods. The aim of this measure was above all to lighten the financial burdens which automobile transport imposes on the State by competing with railways. For this purpose it was decided, in each Department, to form a Co-ordination Committee in which representatives of the railways and of road motor carriers are united to bring about, by joint agreement, the sharing of traffic throughout the area of the Department. These pacts must be sanctioned by Ministerial decrees to become legally binding.

A Central Co-ordination Committee afterwards drew up two regulations which were put into force on the 25th February 1935 (for passenger transport) and on the 13th July 1935 (for goods traffic). These regulations contain detailed provisions as to the contents of regional agreements and the fixing of minimum and maximum rates, timetables, routes to be operated, terms of insurance, etc.

But these regulations will only be of practical utility when the regional agreements shall become law by a Ministerial decree. The drawing up of agreements for sharing traffic, which on principle apportion long-distance traffic to the railways and short-distance traffic as much as possible to road carriers, and the abandonment of certain stations and secondary lines, encountered unforeseen difficulties. Several conventions were signed for passenger traffic but so far none of them have been put into force.

A decree issued the 19th April 1934 forbade the opening of new professional transport services without ministerial authorisation. This step stopped to a certain extent the capturing of traffic by motor vehicles at the expense of the railways. But so far such regulation has had no other practical effects.

In the French North African colonies traffic has to be shared as in France itself

Italy.

Regular passenger services have to be licensed by the Ministry of Communications (Ispettorato generale delle Ferrovie, Tramvie ed Automobili). Applications are scrutinised by a committee on which the State Railways are represented. Competitive services, properly speaking, with the railways are not allowed.

Goods traffic is regulated by a new law (« Disciplina dei servizi di trasporto merci mediante autoveicoli ») passed on the 20th June 1935.

Professional goods traffic must be licensed. The law recognises three classes of transport, viz. :

- a) Transport of goods on demand, including hire of vehicle without a driver;
- b) Public taximeter goods-service (servizi pubblici di piazza);
- c) Regular lines on which goods are carried.

Licences for any of these three categories of transport are only granted to contractors offering sufficient moral and financial guarantees, who are qualified

from a professional and political point of view and who, in addition, are members of the respective corporative organisation. Licenses are granted for a period of nine years; they have to be submitted for approval to the Corporative Economic Council of the province concerned, which above all decides how many licenses are to be granted in the province.

Vehicles licensed to carry goods when ordered are not allowed to park in the streets or public squares and publicly ply for hire.

Public goods taxis must be fitted with an inspected meter and are not allowed to ply beyond the boundaries of the province in which they are stationed.

Concessions for regular goods lines are granted either temporarily for one year or definitely, by royal decree, for nine years. Vehicles and installations of regular lines cannot be transferred without the approval of the Ministry of Transport. In addition, the use of single vehicles on request is not allowed without permission of the Ministry.

As regards goods lines situated within the territory of a railway, the latter has priority for obtaining a concession. To protect goods lines for which a concession has been granted, the law forbids all other contractors to carry on regular or periodical public goods transport between the localities served.

The law contains no regulations regarding rates for goods traffic.

For control purposes, private industrial traffic must obtain a licence, which is nevertheless granted without any proof of necessity having to be given. Paid for goods transport for a third party is forbidden to private traffic.

In order to facilitate a check on the observance of the legal prescriptions, the radiator and rear surface of each licensed vehicle (including trailers) must be painted with a diagonal white, blue, green or red stripe clearly visible, according to whether the vehicle is used for transport on demand, on a taxi ser-

vice, on a regular goods line or on private traffic.

Austria.

For a motorbus service a special concession is required, viz. for regular lines, according to the law passed on the 1st January 1932 concerning motor services and occasional transport in accordance with the regulations respecting professions. Before a licence is granted for a line, the railway concerned is consulted and has a voice in the matter of licensing. In the case of professional licences the railways have no right to be consulted. There are no regulations regarding the rates for carrying passengers.

For professional transport of goods by motor lorries the law passed the 9th June 1933 made licences obligatory. The control of such transport is carried out, inasfar as observance of minimum rates laid down, by representatives of the Federal Ministry of Commerce and Industry selected from among the railway staff. As regards the remainder, control is incumbent upon the political authorities.

Private industrial traffic is not allowed on routes served by the railways except up to distances of 100 km. Transport of goods and passengers not belonging to an industrial concern, as also the use of a concern's lorries for professional transport, is forbidden.

As the application of the regulations concerning lorry transport was only obtained in an incomplete manner, especially from the standpoint of rates, and as negotiations between those concerned were not able to arrange any other solution, the law was temporarily suspended in 1936. But as the situation continued to grow worse, the regulation of motor goods transport was again put into force a short while later.

Switzerland.

Regular professional passenger transport in Switzerland comes within the monopoly of the Post Office and can only

be carried out by private parties after obtaining a licence from the Postal Authorities. Before such is granted, the Swiss Federal Railways have to be consulted. Rates are subject to approval and have to be published.

Occasional professional transport is free and not subject to any control.

Again, transport of goods by motor lorry is entirely free since the law of 5th May 1935 as to division of traffic was rejected. A preliminary enquiry is now being made concerning the revival of the licensing system.

Belgium.

A law passed on the 21st March 1932 made concessions obligatory for all professional passenger transport, regular or occasional. The railways have priority over motor services that chiefly run through districts served by the railway.

Rates are laid down in the specification and vary from 25 to 35 centimes per kilometre (price of third class tickets by rail : 24.5 centimes per km.). Furthermore, the specification stipulates for certain reductions in fares ranging from 25 % to 50 % for men wounded or incapacitated in the war, blind persons, large families, etc., and for the issue of season-tickets at reduced rates. Professional transport of goods was made subject to a concession by the law of the 10th June 1936. The concessions are granted by the Road Transport Office created for this purpose within the Ministry of Transport and are subject to proof of necessity being given. The decisions of this Office are subject to appeal to a Committee; such appeals may be lodged, even after a licence has been granted, by those who consider themselves wronged by such a concession. The law obliges contractors to run their services on sound and economic lines. There are no prescriptions concerning rates. Private industrial traffic remains free; but paid for transport by such persons or firms cannot be done on behalf of third parties.

Luxemburg.

The law of the 10th June 1932 makes the operation of passenger and goods lines subject to a concession.

Holland.

Concessions are only obligatory for passenger lines. Attempts to introduce obligatory licenses for professional transport of goods have failed so far. It is nevertheless anticipated that in 1937 obligatory concessions will be adopted for professional transport of goods.

Denmark.

Authorizations are obligatory for passenger and goods services as well as for occasional professional passenger transport. It is doubtful whether the prescribed rates will be adhered to.

Sweden.

An ordinance issued in June 1933 introduced obligatory licenses for regular passenger and goods services. A service is considered as regular between two localities even when the route taken is not always the same. The operations of a licensed contractor are usually restricted to a given region. Authorisations are granted by the provincial authorities who also lay down the maximum rates.

Norway.

By virtue of the law of the 20th February 1926, a concession must be obtained for regular passenger and goods services.

Finland.

Similar organisation to what exists in Sweden.

Portugal.

The law of the 24th January 1934 made concessions obligatory for professional regular services and occasional transport of passengers. The railways have priority in the case of competitive lines. The concessions stipulate the minimum and maximum rates.

In the case of goods traffic authorisation is only obligatory for regular services.

Hungary.

For passenger traffic, licenses are obligatory both on regular and occasional services.

For goods traffic, contractors must be licensed by the Ministry of Commerce and Communications.

The Hungarian State Railways have received the sole concession for professional goods transport by lorry over the whole of the country, with an obligation to work same through the medium of the National Association of Hungarian Motor Carriers « Mateosz ». As regards the apportionment of traffic, the State Railways have signed an agreement with the « Mateosz », the carrying out of which is supervised by an administrative committee composed of representatives of the State Railways and of the « Mateosz ». This committee draws up the operating programme and takes the requisite control measures.

The competent authority prescribes minimum rates, to be fixed when concessions are granted.

Private industrial traffic is free on condition that it does not carry out transport paid for by third parties.

The regulations governing professional traffic are considered satisfactory by the State Railways. But they add that private traffic is continually increasing; it cannot be hoped to completely stem this movement except by legal regulation of this traffic.

Czechoslovakia

By virtue of the law of the 23rd December 1932, licenses are obligatory for passenger and goods professional transport.

The railways have priority as regards concessions for passenger road services. Since the beginning of 1933 (viz. the time when the law came into force) 1 069

concessions have been granted. The right of priority has only been claimed by the railways in nine cases. In 488 instances the railway management objected to the granting of licenses on the ground that there was no necessity for the new lines in question. In 82 of these cases the competent authorities were of a contrary opinion which, according to the terms of the law, had the result of referring the matter to the joint jurisdiction of the Ministry of Commerce and of the Ministry of Railways. In 39 instances the Railway Administration won the case.

Concessions for professional goods transport are only granted for a restricted area which is all the more restricted as the loading capacity, in weight, of the vehicles used is higher. Holders of concessions are not obliged to adhere to fixed rates. Private industrial traffic is subject to special regulation by Law No. 77 of the 12th April 1935 and by Ministerial Decree No. 165 of the 12th June 1936. These regulations stipulate that firms carrying on private traffic and who have not concluded transport agreements with the State Railway Administration prior to 1st July 1937 will be subject to a progressive tax. If the owner of a lorry agrees not to effect road transport over distances exceeding 50 km. (31 miles) the State Railway Administration is obliged to enter into an agreement.

Jugoslavia.

By virtue of the 1932 law, licenses are necessary for professional passenger and goods transport. Concessions are not granted if harm to existing transport undertakings is apt to result.

For passenger services rates of 0.60 to 0.80 dinars per km. have been fixed. For goods traffic the rates vary according to the weight and nature of the goods and to the length of the line.

Private industrial traffic is not subjected to any regulation.

Bulgaria.

A law passed in May 1935 concerning transport by motor vehicles made licenses obligatory for all passenger and goods professional transport. Rates for passengers, luggage and goods on concessionary lines are fixed by a committee attached to the management of motor services.

Japan.

In 1931 a law was promulgated concerning the operation of motor lines, which makes the carrying of passengers and goods on them subject to obligatory concessions. Concessions are granted by the Ministry of Railways and a severe control is exercised of their whole management. Rates for carrying passengers (2.5, 2.7, or 3 sen per km.) are progressive, contrarily to railway rates which decrease as distance increases. The operators are obliged to issue season tickets at reduced rates.

As motor lorry goods traffic in the form of regular lines is of secondary importance, the law principally applies to passenger traffic.

(d) Taxes on motor vehicles.

At the beginning, taxes on motor vehicles represented a contribution paid to the State for the special use of roads by the new means of transport, and usually paid in the shape of an inclusive tax. As it grew, motor vehicle traffic was more and more considered as a fiscal resource and made to contribute towards the State's financial requirements. But concurrently expenses for road building and maintenance increased. The tendency to face these outlays by means of taxes on motor vehicles made itself more and more felt. But no distinction between taxes considered as a contribution to roadmaking and maintenance charges and those levied for general fiscal purpose was made, whilst on another hand nowhere was an attempt made to exactly ascertain the total road expenses due to

motor traffic. Thus, in all countries the question as to whether motor vehicles contribute a sufficient share of this outlay is still necessarily a controversial one at the present day. Nevertheless, it may be admitted as certain that it is precisely the increase of the State's financial requirements, the result of the expenditure on roads, which led to a search for new sources of receipts and that the latter were found in the taxation capacity of motor fuel. Taking advantage of this source of revenue was bound to appear all the more justified because it constituted a method of taxation which takes into account to a large extent, the amount of wear caused to the road by each vehicle. As to the proportion in which professional motor carriers were to bear supplementary taxes, calculated according to their importance, the authorities were guided by considerations of a purely fiscal nature.

The aggravation of the conflict between rail and road had the result of introducing a third and new factor in the question of motor taxation. As the State could not avoid intervening in this discussion, it was clear that it ought to support its intervention by fiscal steps and place motor taxation at the service of regulation, desired by the State, of co-operation or competition between rail and road. This method of reasoning is, moreover, becoming more and more apparent in the most recent forms of motor taxation.

To the three aims of the taxation policy :

Contributions to general financial requirements;

Contributions towards road building and maintenance;

Taxes inherent to the transport policy, there correspond, in fact, nowadays three methods of collection :

Fixed lump taxes;

Indirect taxes on fuel and tyres;

Taxes levied on distances run or transport done by vehicles.

The oldest tax in most instances on motor vehicles, i.e. a fixed sum, was originally and undoubtedly still is to-day of a mixed nature. Being independent from the distance run by each vehicle, and consequently not being proportionate to wear and tear of roads, it is essentially of a purely financial nature. But, on another hand, it usually increases as the weight of the vehicle or the power of the engine rises. Apart from the consideration, also of a fiscal nature, that larger vehicles are also capable of giving better returns, it would appear that here the element representing an obligation to contribute to road expenses has played a decisive part. On the contrary, an all-round tax is badly adapted to the aims of a traffic policy. Indeed, the raising of a tax has, after all, the purpose of restricting the very traffic on which it is levied or hampering its development. Now, increased taxes have the consequence of creating higher overhead charges and the latter in turn demand a more intensive use of vehicles, whence, according to circumstances, the opposite of the result anticipated.

In most countries the total annual taxes are based on the actual weight of vehicles in working order. It is under this form that they exist in Germany for motor lorries, in France and Belgium, also for lorries (in France an over-loading or « encumbrance » tax has been added); in Holland, Denmark, Sweden, Norway, Finland and Bulgaria lorries are taxed according to their loading capacity and in Czechoslovakia there is for lorries a tax varying according to actual tare weight and also another based on tonnage (*).

In a few countries the total tax varies according to cylinder volume; such is the case in Switzerland, in Belgium, in

Italy and Czechoslovakia for light vehicles.

In France the law of the 23rd December 1933 did away with a total tax on light vehicles and substituted a corresponding tax on fuel for it. It was thus intended to establish a more exact proportion between taxes and actual wear and tear of roads (Nevertheless, for lorries total taxes were considered as necessary).

On the other hand, it is to reasons dictated by the transport policy (and also to economic reasons) that one should attribute the fact that in Germany motor vehicles for passengers, put into circulation after 1st April 1933, have been entirely exonerated from the total tax (Motorisation). In Austria, also, the tax levied on automobiles since 1931 was abolished in 1935.

Objectives of transport policy are also aimed at in Italy, where the total tax calculated on the basis of the power of the motor differs according as whether the vehicles in question are for public or private use. Moreover, as we have already pointed out, the legal provisions governing concessions in Italy have as their final aim an efficacious protection of public line services.

A remarkable attempt to make a total tax serve the objects of the traffic policy was made in Czechoslovakia. Law No. 77 of 1935, to which reference has been made above, lowered the former tax on passenger transport (which only, moreover, affected professional traffic) and abolished the tax on goods traffic. At the same time, taxes on tonnage and actual vehicle weight were increased to the rates applicable at present, viz. 32.50 Czech crowns per 100 kgr. tare and loading capacity of lorries, 35 Czech crowns per 100 kgr. actual tare of omnibuses, and 70 Czech crowns per 100 kgr. loading capacity of trailers. For private in-

(*) For motor buses, account is only taken of the weight of the vehicle itself.

dustrial traffic there is, in case of dispute with the railway, an additional tax as follows :

For vehicles of less than 1.5 tons dead weight :	...		
» 1.5 to 2.5 tons	»	60 %	} of the ordinary tax on weight.
» 2.5 to 5.0 tons	»	100 %	
» more than 5.0 tons	»	200 %	

The idea of a transport policy is clearly visible here : professional goods transport being restricted to given distances, it is not necessary to burden it with further taxation. The same applies to private industrial traffic if, and to the extent that it submits to a voluntary restriction; in the contrary case an appreciable additional tax is imposed. As the whole system is more or less intended to protect the railways, the taxes have also been somewhat increased as a whole.

The additional tax on private industrial traffic will only be applied from the 1st July 1937 onwards. It will be interesting to see what results will be obtained.

Customs dues and taxes on fuels exist in all countries with the exception of Hungary. Everywhere the curious fact can be noticed that taxes on heavy oils are much lower than those on petrol. Owing to this fact, diesel-engined lorries, with their fuel already costing less, enjoy a privileged situation which is hardly justifiable.

In Sweden and Norway there are in addition special taxes on rubber tyres.

Hitherto, in no instances have taxes on fuels been adapted to the objectives of the transport policy, unless the raising of the Customs dues on petrol in Switzerland on and after 1st July 1935 (after the law for the sharing of traffic was rejected) be considered as a step to protect the railways. It is true that in this instance the result should be considered as entirely negative, for it has not been able to stop a further aggravation of lorry competition and has at the most, owing to lack of regulations in the matter of concessions and of a rational control of the management of transport

undertakings, led to complete disorganisation of the lorry transport industry.

The situation is somewhat different in Germany, where the tax on fuel has recently been increased with a view to the financing of the Reich's motor highways and also doubtless for the purpose of somewhat restricting motorisation.

Taxes intended to further a transport policy have found their widest, and probably also most efficacious field of application in dues calculated on the basis of production. In Germany there already existed since a fairly long time, as regards professional goods transport, a general transmission tax of 2 %, which is still applied at the present time to professional goods transport over short distances. In order to avoid upsetting the financial equilibrium of the Reichsbahn it was found necessary, in 1936, to raise its goods rates by 5 % on an average. If the requisite protective steps had not been taken, there would have been an immediate resultant exodus of traffic to road carriers. To prevent that, the 7 % tax on rail transport was extended to long-distance professional goods transport, whilst applying, in addition, to the latter the essential parts of the higher railway rates. But there was the danger of traffic going over from professional carriers to private industrial transport. In order to obviate it, the tax of 0.6 pf. per tonne-kilometre carried was also applied to private industrial traffic.

For passenger motor transport a tax was also imposed, to take effect from 1st March 1937. It is collected from occasional and regular passenger services, as also from passenger transport by the Post Office and Reichsbahn motor vehicles. On regular services this tax amounts to 12 % of the net transport

price or 10.71 % of the tariff rates, and on occasional services to 0.3 pf. per passenger and per kilometre of line covered.

A similar evolution has taken place in Italy. The deficit of the State Railways in recent years formed an ever heavier burden on public finances and was becoming excessive. There was therefore a general raising of goods rates, accompanied by a corresponding tax on motor vehicles, or 12 centesimi per tonne-kilometre on professional transport, and 8 centesimi per tonne-kilometre on private industrial transport.

It was in no wise by chance that in Germany and Italy, in order to achieve the aim, which was to prevent an aggravation of motor competition after the raising of railway rates, the authorities chose the form of a tax applied per tonne-kilometre (in Italy per 100 kgr./km.) A fixed tax would not have met the requirements, as its effect would have been weakened by a more intensive use of the vehicles taxed, whereas motor vehicles used less extensively, and consequently playing a smaller part in competition, would have been taxed to an excessive extent. The application of a tax based on the kilometres covered by vehicles corresponds already better to actual production. Again, an increase of taxes on fuel would be more indicated but it would have the drawback of also affecting other traffic (such as private automobiles) which it was not intended to penalise by a higher burden. It is true that this step has also been taken in Italy, even to a very considerable extent. But the reason for that was not one of traffic policy but rather necessity of economising fuel owing to the Abyssinian campaign. After the conclusion of the latter, the price of petrol has again somewhat dropped in Italy.

As regards co-ordination between rail and road provision has also been made in France, for a tax per tonne-kilometre of transport. The decree of the 13th July 1935 institutes a system of taxes com-

prising rates of 10 to 25 centimes per tonne-kilometre according to the kind of goods transport (regular lines, house-to-house services, removals, etc.). Short-distance traffic is exonerated from this tax. Long-distance traffic has to bear higher taxes than traffic over medium distances (the decree defining what is understood by short, medium and long distances). The highest taxes should be collected on all occasional long-distance goods traffic.

In France also, the authorities had to take care to prevent professional transport from diminishing in favour of private industrial traffic. For that purpose a decree dated the 30th October 1935 provided for a tax on private traffic to be collected when a lorry belonging to an industrial firm runs beyond the borders of Departments adjoining that to which it belongs.

As the execution of the French co-ordination plan as a whole encountered difficulties and was consequently retarded, the taxes mentioned above have not been applied so far. On another hand, professional goods transport is subjected to a 2 % transmission tax which is naturally of an exclusively fiscal nature.

Again, there is in Austria an additional professional transport tax called « Verkehrabgabe », which is 3 % on all taxes levied.

In Italy public passenger transport by rail and by road are subject to the same taxes.

In Belgium a tax of 2 1/2 % is collected on professional goods carriers. Motorbuses equipped with petrol engines pay 5 centimes per kilometre run and those having diesel engines pay an additional tax of 2 1/2 % on the fares. On regular motorbus services there are rebates on taxes.

In Czechoslovakia motorbuses are subject to a tax of 20 % on the prices of tickets. Prior to the 1st July 1935, it was 30 %, but was reduced in connection with the reorganisation of the sys-

tems of total taxes by Law No. 77 mentioned above. Taxes are reduced on motorbus lines that do not compete with the railways.

In Bulgaria also, motorbus undertakings pay a tax of 10 % on the price of tickets.

A comparison between the various countries from the point of view of fiscal steps affecting motor transport is extremely difficult or, rather, almost impossible owing to the variety of taxes levied. But even if we succeeded in reducing the absolute numerical values to a common denominator, a comparison of this kind would not be of much use; conditions differ so much from one

country to another as regards the purchasing power of money, density of motor traffic, expenses for road maintenance, general structure of traffic, raising of railway rates, etc., that it is not possible to formulate any definite conclusions based on the absolute figures representing taxes levied on motor vehicles.

In many countries it is not even possible to compute the total product of such taxes, because the share of motor vehicles in import duties on petrol, taxes on business turnover, etc., is not known. The precise information we have received with regard to the product of taxes on motor vehicles will be found in the table reproduced below :

Product of taxes on motor vehicles in a few countries.

(in millions of the respective currencies).

—	1929	1934	1935
Germany (total tax only)	209.5	145.5	135.3
Austria (tax on petrol and tax on transport)	—	41.0	45.9
Switzerland (total tax only)	22.5	30.7	30.9
(import duty on petrol)	30.7	47.9	55.4
Holland (taxe on weight)	9.4	14.8	20.7
Denmark (tax on weight and on petrol)	41.2	63.6	70.8
Sweden (tax on petrol, on weight and on tyres)	39.8	78.5	87.5
Norway	5.5	18.9	22.4
Czechoslovakia: total revenue from taxes	200.9	366.0	377.5
deduction for road fund	158.2	237.2	260.2

Except in Germany, where the fixed tax has been abolished for motor vehicles put into service since 1st April 1933, the product of taxes shows everywhere a tendency to rise. This fact is partly attributable to the extension of motori-

sation and partly to the increase of taxes levied on motor vehicles.

The following table shows how the taxes that are levied on a 5-ton lorry increase with the distances covered in the different countries; this table shows,

in addition, that everywhere, except in Belgium, lorries propelled by means of diesel engines are decidedly favoured from a taxation standpoint:

Annual total taxation on a 5-ton lorry.
(in the currency of the respective countries).

	Petrol engines.		Diesel engines.		Remarks concerning private traffic. (Werkverkehr.)
	30 000 km.	50 000 km.	30 000 km.	50 000 km.	
France	6 050	9 150	4 400	6 400	Not including tax on turnover, not payable by private traffic.
Switzerland . .	4 150	6 430	2 390	3 440	Same taxes.
Belgium	5 000	5 000	10 000	10 000	Not including transport tax, not payable by private traffic.
Holland	1 350	2 420	485	485	Same taxes.
Denmark	2 300	3 100	?	?	» »
Sweden	2 370	3 640	taxation reduced.		» »
Norway	2 000	3 400	1 100	1 600	» »
Hungary	600	600	600	600	Private traffic: 800.
Czechoslovakia .	18 300	29 000	8 250	11 550	On and after 1/7/37, as the case may be, an additional tax on private traffic: 6 500.

III. — Defensive steps taken by railways.

1. Changes in the organisation of railways.

In all countries the crisis and motor competition have obliged railways to organise their services on bases as economical as possible. Outdoor departments, as well as work in the Management's Headquarter Offices, have been constantly simplified and rationalised. On almost all systems, staff has been reduced considerably as compared to 1929, and when and where it has again been increased in recent years the staff increase has not always been proportional to the increase in traffic. As rationalisation of the services of undertakings such as large railways, with their numerous ramifications, requires an infinity of small operations

to be repeated, which cannot be done at one and the same time, it is still being perfected on most systems. Everywhere the chief object is to reduce expenses.

On the other hand, during the last few years only few radical changes have been made in the organisation of Railway Administrations. In Germany, we might mention the creation of the Reichsbahn's auxiliary undertaking called « Reichsautobahn ». In Algeria the State Railways and the North African lines of the *P.L.M.* system have been merged into one joint concern, similarly to what was done a few years ago by the French *Paris-Orléans* and *Midi* companies. In Austria two Departments of the Federal Railways were merged in 1932; in Czechoslovakia the State Railways have also done away with one Department. In addition, the latter Railways have created, as regards motor vehicle ser-

vices operated departmentally, special divisions and they reckon thus to increase receipts.

On another hand, the tendency to make the commercial service a more autonomous organisation, either by separating it from the technical operating department or by reserving within the latter a more independent place for it, is making itself more and more apparent. On the Italian State Railways complete separation exists, not only within the General Management and District Managements but also in main stations in which the slow goods traffic staff is under the orders of the Commercial Department and not of the Operating Department.

In Belgium more frequent and closer relations have been established with customers by the creation of special Commercial Agencies in important localities.

On the Czechoslovak State Railways the Commercial Service constitutes an autonomous entity up to within main stations.

2. Publicity Department.

Competition by motor vehicles has caused all railways to pay ever greater attention to their Publicity Departments. This task has been entrusted in certain cases to special organisations created for this particular purpose.

In Germany publicity for passenger services is carried out in the first instance by the *Mittleuropäische Reisebüro* (MER) which was set up by the Reichsbahn and works in close collaboration with it. On the other hand, the Reichsbahn ensures publicity for goods traffic by means of its own agents. It has opened in Berlin a special office which is in touch with information bureaux situated in other large localities.

The French railway companies have created a joint publicity service. Propaganda for goods traffic is entrusted

by the railways to special commercial agents who attend solely to this task.

In Italy, the State Railway Administration collaborates, for stimulating travel, with the Press and Propaganda Ministry. For goods traffic the Railway Management is seconded in its publicity by the « *Istituto Nazionale de Trasporti* » (INT), which acts as a connecting link between the railway and its clients and also undertakes the organisation of ancillary railway services.

A similar situation exists in Austria where the Federal Ministry of Commerce and Communications manages the travel publicity.

For publicity concerning passenger traffic, the Swiss Federal Railways have a separate advertising department and maintain a number of agencies abroad. Furthermore, they participate financially in the « *Centrale Suisse des Transports* », a semi-official organisation which handles all the interests of the country as regards travel.

For goods traffic, the Swiss Federal Railways have founded jointly with other Swiss Railway Managements an independent subsidiary Company the « *Société Anonyme Express Suisse* » (SESA), which undertakes to canvass clients for goods traffic and is authorised, within the scope of the respective contracts, to grant reduced rates for the purpose of recuperating traffic from road carriers or to prevent losing such traffic. The uniform organisation of subsidiary railway services is also entrusted to it in certain instances.

A typical publicity service is that of the Belgian Railways, which has been organised and is worked by the Company itself. To each Operating Division there is attached a travel bureau. For propaganda concerning goods traffic special commercial representatives are maintained at important places.

The Netherlands Railways have their own publicity department; the same ap-

plies to Scandinavian countries, who advertise with their own staff.

For goods traffic the Danish State Railways have established an independent agency which maintains branches throughout the country. The latter work in close collaboration with the railway.

The Portuguese Railways Company maintains, like the French and Belgian systems, special commercial agents.

The Hungarian State railways have entrusted a branch (« Ibusz ») with their publicity. In addition, they collaborate with the Hungarian travel bureau. On the other hand, the « Mateosz » Association of Carriers canvasses for goods traffic by rail and road combined.

The Czechoslovak State Railways have organised a publicity bureau at each Management headquarters. These bureaux collaborate with the « Cedock » (national travel bureau), which maintains a number of agencies in the country and abroad.

In Japan, where the Government Railway Management is incorporated in the general State Administration, the publicity service is also carried out by State agents. For this purpose, there is a general Touring Management. The Government Railways collaborate in addition with the « Japan Tourist Bureau ». For goods traffic they maintain special information agencies in important localities.

In addition, all railways naturally use for publicity purposes their vast system of stations and goods receiving offices, whose staff is becoming more and more trained in publicity methods.

Where special and independent organisations have been created for publicity purposes, the latter usually function in the joint interests of several companies. On the contrary, services operated departmentally are usually restricted to the undertaking to which they belong.

An increasing tendency is noticed to carry out tourist propaganda, especially abroad, on a national basis and make it

serve not only the interests of the railways but also those of touring as a whole. It generally then receives important State subsidies (e.g. Germany, Italy with its « Ente Nazionale Italiano di Turismo » (« ENIT »), Austria, Hungary and Czechoslovakia).

Independent branch organisations are usually supported financially by the railways, either in the shape of commissions on their bookings, or fixed grants. In Austria the annual contribution from the Federal Railways towards publicity expenses of the Federal Ministry of Commerce and Communications must not be less than the net product obtained from the railway publicity monopoly.

Railway agents entrusted with publicity work do not generally receive special grants, apart from their expenses. Only the Italian, Swedish and Czechoslovak State Railways grant a certain premium to agents who have rendered distinguished service in publicity matters.

In proportion to the total operating receipts the outlay of Railways for publicity purposes are usually kept within moderate bounds. As many Administrations do not show this separately in their accounts, it is not possible to make a comparison. According to information supplied it varies from 4 to 10 ‰. But, speaking generally, it has been noticed that such expenditure has shown a tendency to increase in recent years.

The advertising methods are practically the same everywhere. More and more importance is being paid to personal contact with clients of the railways. In addition, the following means are used : booklets, posters, films, wireless, interviews granted to newspaper reporters, press visits, announcements, advertisements, periodical propaganda reviews, almanachs, diaries, etc. It may be of interest to mention an item of information supplied by the Portuguese railways : they have the right to demand

free insertion of advertisements in the newspapers in return for carrying the latter free of charge.

The Belgian National Railways Co. communicates the following interesting information as to the guiding lines on which it carries out its various methods of publicity :

Posters must be of an artistic nature, as they are intended to constantly remind the public of services of a permanent nature which the railways render. They help, moreover, to decorate stations. Posters are intended to awaken general interest, whilst referring the public to railway offices for details. The latter are supplied with booklets, handbills, etc., which the booking offices hold at the disposal of the public.

Announcements in technical reviews, etc., usually give good results. Thus, subscribers to a textile trade journal, for example, are specialists who are interested both in details concerning their production and in the transport of their goods. But advertisements must appear in the midst of the reading matter, for it is known by experience that those which appear on special pages either in front of or behind the ordinary reading matter are less perused.

In order to make temporary transport facilities known it is advisable to distribute tracts wholesale, eventually through the post.

The results which are easiest to check are obtained by direct contact with the parties concerned. But such contact must be backed up by distributing publicity booklets which are brought to the mind of the public by posters and other publications.

3. Improvement of services.

(a) Passenger services.

All railways without exception strive to improve passenger accommodation by a better fitting out of coaches, not only on fast trains but as a rule on all pas-

senger trains. Thus, in Germany, Holland and Denmark especially, a start has been made in upholstering third class coaches. In Czechoslovakia dancing-cars have been introduced as a trial.

Most railways have found that both the economic situation and improved comfort in third-class coaches have tended to cause passengers to abandon the higher classes. In Belgium this change-over has been amplified by the abolition of first-class coaches on the fast electric interurban service between Brussels and Antwerp. In Denmark, apart from main-lines expresses, there is now only one class. Therefore, change-over there has only made itself felt to a slight extent. The Czechoslovak Railways have succeeded in slowing down this change-over by reducing the difference in fares.

On the other hand, it has been ascertained as a rule that passengers have not forsaken fast trains, on which a supplement has to be paid, for ordinary trains. It is only on the Austrian Federal Railways that a certain forsaking of expresses with supplementary fares has been noticed, and that is due to a multiplication of fast trains running according to the time-tables of former expresses.

Almost all Railway Administrations are of the opinion that the steps taken to improve the comfort of passengers have given favourable results in fighting motor-vehicle competition. Thus, the French Railways consider as an efficacious means of competing, the adding of third-class coaches to long-distance expresses and a reduction of the minimum distance demanded to make use of such trains. The Austrian Federal Railways have found that it is above all comfortable rail motor coaches which have recovered part of their traffic lost to road.

The Belgian Railways are of the opinion that higher train speeds and frequency are of more help to regain

passenger traffic than improved comfort. Nevertheless, they are paying attention to the latter and the proof of this is that henceforth, on all fast trains, old running stock is being replaced by modern all-steel coaches; in fact, in two years time all passenger trains will consist of modern all-steel coaches.

Several Administrations, among which the Belgian National Railways Co., mention electrification as a particularly efficacious means against losing passenger traffic.

The Czechoslovak State Railways express the opinion that, given equal prices, the improved comfort of railways has made passengers prefer them to motor vehicles on the roads.

All railway Administrations without exception are trying to increase the speed of passenger trains as a whole. This object is achieved above all by shortening stopping times, eliminating stops that are not absolutely necessary, and exactly adapting the composition of trains to actual requirements, in order to reduce dead weight. They are above all striving to raise maximum speeds on main-line long-distance expresses. The German State Railways have, on most main lines, increased the all-round maximum speed of fast trains from 100 to 120 km. (62 to 75 miles) per hour, and certain of these trains now run at a speed of 160 km. (100 miles) an hour.

All Railways are making a more and more extensive use of rail motor cars driven by electric motors or internal-combustion engines. They are mostly encountered in the two following forms : on the one hand, the railways use railcars or rail motor trains on particularly fast long-distance routes with high maximum speeds; on another hand railcars are used to increase train frequency and accelerate short-distance traffic, paying special attention to the importance of quick acceleration, which is facilitated by a saving in dead weight. In Switzerland light railcars have above

all been successfully used for excursion parties. The opinions expressed as regards results obtained from the use of railcars are generally favourable.

The opposite method, which consists, in view of the economic situation and loss of receipts to railways, caused by automobile competition, in reducing the number of trains and lowering their speed, in order to effect savings, has nowhere been adopted on a large scale. In Belgium, this solution was tried out during the first years of the crisis, but its lack of success soon became apparent. This method was, furthermore, rapidly abandoned and replaced by a general acceleration and multiplication of trains. The National Railways Co. is satisfied with the results obtained.

The Danish State Railways state that, having reduced the train service on a few secondary lines, the traffic fell off appreciably.

If the Italian State Railways discontinued a certain number of little used trains, during the period of economic sanctions, the reason must be ascribed to the particular circumstances of the moment, with the result that no special conclusion can be drawn therefrom.

The Austrian Federal Railways consider that it is advisable to reduce train workings to the absolute indispensable minimum during months when traffic is really light and, on the contrary, run more and faster trains during the season of great activity.

It is only in France and Holland that passenger train operation on secondary lines has been discontinued to a fairly large extent. In Holland this step extends to 16 % of all lines. In other countries such measures have only been taken very rarely. In Sweden, Norway, Finland, Portugal, Hungary, Yugoslavia, Bulgaria and Japan passenger services have been maintained integrally on all lines of the main system.

All railway managements are agreed in stating that the running of railcars

and light trains has a twofold aim, viz. :

1. to increase train frequency;
2. to reduce traction costs.

(b) **Goods services.**

Acceleration. — The desire to carry goods at a faster rate is general. In order to enforce this legally, delivery times have been shortened in a few countries. Thus, France and Czechoslovakia have abolished excess delivery periods that applied to certain exceptional rates.

The Belgian National Railways Co. endeavours to work all parcels traffic according to the now admitted formula : « Accepted to day, delivered before noon to-morrow ». The same programme has been adopted by the Czechoslovak Railways for deliveries at a distance not exceeding 200 km.

In France the Railways have created, for all packages weighing less than 50 kgr. (110 lb.) one single transport speed which is equivalent to that of an express goods service.

Acceleration of parcels traffic has led a few Administrations to separate it from complete loads in goods trains running short distances. Collection and delivery of parcels is done by a fast shuttle service, similar to the German « Leigs ».

The tendency towards rapid goods transport has had the result, on the one hand, of making passenger trains carry more goods. But, on another hand, the acceleration of passenger services has also had the result of dispensing many

passenger trains from accessory tasks. This step has been taken notably, in Germany, Holland, Denmark and Switzerland.

Extension of door-to-door services. — In many countries cartage rates have been continually lowered. We would especially mention the reduction of 50 % in Germany, taking effect from 1st April 1936, of cartage rates for complete loads of the three higher classes of rates.

In France cartage rates have been unified in all important centres.

Many railways take an active part in cartage services; such are the Italian State Railways by means of the « INT » (Istituto Nazionale Transporti), the Swiss Federal Railways through the SESA (Schweizerische Express A. G.), the Austrian Federal Railways through the RONA (Rollfuhr-, Nahverkehrs- und Speditionsgenossenschaft), the Czechoslovak State Railways through the SPEDRA.

In Holland free delivery at domicile is included on principle in all parcels rates, i.e. no special fee is collected.

With a view to reducing cartage rates still further, many Railway Administrations grant important *subsidies* to cartage services. They adopt, in so doing, the principle that from a financial standpoint it comes to the same thing whether they suffer losses of receipts by lowering transport rates on the railway lines or whether they help to lower cartage rates by granting subsidies to cartage services.

These subsidies amounted in 1935 to the following sums :

German State Railways	15 million RM.
Swiss Federal Railways	180 000 francs.
Belgian National Railways Co.	9.2 million frs.
Netherlands Railways	4 million florins.
Danish State Railways	97 000 crowns.
Swedish State Railways	277 000 crowns.
Norwegian State Railways	36 000 crowns.

The Czechoslovak State Railways grant varying subsidies in case of need, i.e. where there is competition.

Under the heading of door-to-door transport we also find an increasing use of *containers*, of which there are at present in service :

	Small containers.	Large containers.
German State Railways	16 000	250
Austrian Federal Railways	100	...
Belgian National Railways Co.	1 520	...
Netherlands Railways	153	25 (*)
Japanese Government Railways	2 500	...

Furthermore, the use of containers is beginning to develop in France, Italy, Sweden and Czechoslovakia.

A few Railways have also introduced vehicles transporting complete loaded wagons from door to door by road. The Reichsbahn has 45 « Culemeyer » vehicles in service, which give satisfaction. Italy also uses them and Japan is building some. In France use is made of the « Willème-Coder » wagon which runs on rails on four wheels. When it passes on to the road two rubber wheels are lowered on to the rear wheels, whilst the front part rests on a tractor.

Storage. — This service exists on the German, Swiss, Austrian, Belgian, Dutch and Czechoslovak Railways. In Belgium, Holland and Switzerland the rates collected for this have been reduced (in Belgium when railway rates were lowered by 10 % on 20th January 1935 conjointly with most sundry charges).

Cartage and forwarding agents. — Most railways grant to grouped consignments of forwarding agents special rates which are sometimes (in Belgium for instance) subordinated to the condition that all the firm's traffic is passed to the railway. In Hungary grouped consignment traffic from forwarding agents has been discontinued; however, door-to-door service with the collaboration of forwarding agents has been extended.

The German State Railways, through its subsidiary the « Deutsche Bahnspedition », closely control the work of for-

warding agents' traffic, including the rates to be paid by clients.

In Czechoslovakia, under the auspices of the State Railways, there has been founded the « Spedra » Association which groups most of the forwarding agents in the country. The « Spedra » organises grouped consignment services wherever rail traffic is threatened by road competition.

The Railway grants to the « Spedra » a uniform commission on all goods forwarded by its members. This commission is paid into a fund from which the « Spedra », in agreement with the Railway Administration, effects individual payments to the various forwarding agents in the shape of grants, which are fixed for each traffic route, according to the extent to which it is threatened by road competition and which depend, in addition, on the quantity of goods forwarded by each member of the Association. No commission is paid on shipments to over 300 km. (186 miles) distance.

Various steps. — In a few countries Railways have also considered it necessary to themselves undertake, in given instances, the loading and unloading of complete wagon loads. In Germany this operation is included in the cartage rates of the three higher classes of full wagon loads. The Belgian, Swiss, Hungarian and Czechoslovak Railways perform this against payment of a special rate which, in Switzerland, however, is not levied in certain cases.

(*) Plus 685 cases for transporting cheese.

4. Tariff measures.

(a) Passenger traffic.

Speaking generally, the prices of passenger tickets have not undergone any all-round reduction in recent years. Exceptions are encountered in Norway, where fares for distances shorter than 300 km. (186 miles) have been reduced; Finland has, generally speaking, reduced 1st-class fares. In Czechoslovakia passenger fares have been lowered 10 % all round, the effect of this having made itself felt on long-distance runs. In Yugoslavia the prices of tickets, which were reduced by 30 % in 1928, were again raised 10 % from 1st March 1935 onwards. Bulgaria introduced a general reduction of 25 % temporarily from 15th May to 15th September 1935. In France and Italy rates were generally simplified and partly lightened. In Italy numerous special permanent reductions were introduced at the same time, which means that in the future only 40 % of the passengers will pay the full rates.

In all countries (except Yugoslavia) the Railways issue combined tickets for journeys by rail, road and boat; a few countries have also instituted combined rail-air tickets.

Furthermore, there are tickets in a number of countries which include not only the railway journey, but also hotel expenses, meals, entrance to theatres, dance-halls, race-courses, bathing-establishments, etc. (inclusive travel). In some countries such combined tickets are not issued by the railways themselves, but only by travel agencies. Some railways (e.g. the Swiss Federal Railways) do not issue them in a general way, but only to groups organised by the Railway. In Austria, Belgium, Czechoslovakia, Yugoslavia and Bulgaria there are no inclusive tickets.

Since 1st January 1935 the following

special price reductions have been made in the various countries :

Germany. — Temporary reductions to visit war graves, increased reductions to large families, rebate on price of season tickets (to facilitate living in the suburbs of large cities), extension of reductions for special holiday trains, reduction in price of season cards for travelling all over the system and the creation of season tickets also available on other connecting systems.

Special steps taken against road competition : Reduced price for parties of the German League for Physical Culture, reductions on scholars' season tickets, reduced rates for parties by lowering to 8 the minimum number of persons comprising such.

France. — Extension of special rates for parties, issue of season tickets for booking half-fare tickets, reduced rates for motor cars whose owners travel by train.

Italy. — Extension of weekly tickets for employees and workmen; introduction of new regional season cards; general introduction of return tickets up to 250 km. (155 miles); circular tour tickets at reduced rates; introduction of season tickets available over the whole system, of short duration; reduced rates for week-end fares of persons travelling singly and parties of at least 5 persons; reduced rate winter-sport tickets; holiday tickets for families; reduced rates for foreigners making a minimum stay in Italy; family tickets; reduced rates for parties; issue of cheap tickets for exhibitions, congresses and other events; the running of popular-priced trains at very low rates in summer.

In addition, luggage rates have been lowered by 30 %, and rates for dogs, bicycles and motor cycles have been reduced.

Austria. — Cheaper tickets for summer trips from 1st July to 27th August

for 7-day holiday vacations; similar reductions in spring and autumn. Other reductions for certain particular cases.

Switzerland. — Reduced rates for general season tickets and a trial-reduction of 10 to 20 % for 1-day party tickets.

Belgium. — Reduced rates for parties; facilities for sporting associations, scholar parties, etc.

Luxemburg. — Creation of tourist season tickets; reduced rates for parties and scholar excursions.

Holland. — Extension of return tickets to the whole system and new facilities for use of same.

Denmark. — Occasional reductions for parties; lower rates on a few shipping lines.

Sweden. — Extension to 10 days of validity of return tickets. Issue of family tickets for distances of at least 150 km. (93 miles).

Norway. — Introduction of return tickets for distances up to 300 km. (186 miles).

Hungary. — Extension of price reductions on journeys to health resorts and to the Plattensee.

Bulgaria. — Organisation of « hospitality weeks » in favour of certain towns (reduction of 70 %); lower rates for scholars.

Japan. — Reduced rates for trips to winter-sport mountain resorts, and seaside resorts; introduction of circular tickets, family tickets and week-end tickets.

The Administrations consulted express their satisfaction with the results of the various steps they have taken. However, the temporary general 25 % lowering of rates in Bulgaria was not a success; with special reductions, and above all with the so-called « hospitality » weeks, much better results have been obtained.

(b) Goods traffic.

In Germany there was a general increase of 5 % on goods-rates from the 20th January 1936. Only certain products and exceptional tariffs were exempted from same. From the 1st October 1936, these supplements were incorporated in the goods rates, which were also simplified all-round on that occasion. The reason for the rise in goods rates, which in no way altered the general structure of the tariffs, has already been stated.

In Italy, also, the goods rates were generally increased by an average of 25 % on and after the 1st January 1936. The rise in the various transport rates varies from 10 to 35 %. As a rule, it is the long-distance rates and specially low tariffs which were most raised. There was a resultant remodelling of the structure of the rates system, which has brought about a comparative lowering of rates for short distances and for the higher categories of the tariff, a lowering which is clearly directed against motor vehicle competition. We have already discussed the far-reaching reasons for this rates reform.

In Belgium goods rates underwent a general reduction of 10 % on the average, to take effect from the 20th January 1935. In this instance, also, the reduction was greatest on distances not exceeding 75 km. (46.5 miles), in order to combat motor competition. But the result has not fulfilled expectations. In fact, traffic on short runs has not increased; it is rather on distances of over 75 km. that it has increased. On the other hand, in Belgium there was no comparatively greater lowering of the high rates in the tariff.

In the autumn of 1936, Norway also lowered its goods rates all round, by lowering to a greater extent rates for short distances and the higher classes of the tariff.

In Jugoslavia, owing to the economic crisis, rates on cereals, millers' products, fodder and vegetables were lowered all round (an agricultural country).

In Japan there was in 1935 a general tariff reform, consisting of the creation, for parcels, of a much reduced door-to-door (« Takuatsukai ») general tariff, which is not based on values.

In other countries, there was no general reduction of rates, even in the shape of a lowering of tariffs for short distances or high-rated goods, apart possibly in Denmark where a general exceptional tariff was introduced, providing for reduced rates for distances not exceeding 125 km. (77.5 miles).

Tariff measures taken in various countries to meet automobile competition are of a fairly uniform nature. Everywhere the authorities have been satisfied with taking special measures in cases where they appeared the most urgently required. In all countries big customers are granted rebates on a quantitative basis, often made subject to a clause providing that all traffic will be sent to the railway. In certain cases where an important category of traffic is specially hit by competition, the railways can grant more or less considerable rates reductions. Some countries make a scale of these reductions, by making them proportionate to traffic relations. We ought to mention the method of the Austrian Railways which make the granting of exceptional rates for certain raw and other materials subject to the condition that the finished goods will be forwarded by rail. In Switzerland it has become the rule to insert in certain exceptional tariffs a clause stipulating that the rates granted therein are only for consignors whose goods named in the tariff are exclusively despatched by rail, for distances of over 25 km. (15.5 miles).

It is only in Germany that competitive rates to fight road transport are not authorised.

5. Participation of railways in motor transport.

(a) Passenger traffic.

At the present time the following Administrations participate in passenger traffic by means of motor vehicles which belong to them and which they operate departmentally: The German, Danish, Swedish, Norwegian, Finnish, Czechoslovak and Japanese State Railways and the Portuguese Railway Co. Among such motor services the first place is taken by regular lines acting as feeders to the railways and serving districts where there are no railways. In a few countries motor vehicles replace trains on secondary lines and thus contribute to effect a saving in operation. Occasional trips are also made in some cases, but play a less important part than the two above mentioned services.

The Austrian Federal Railways have formed a subsidiary concern, the « Köb », for carrying passengers by automobile; it operates 259 of its own omnibuses. The latter are used to act as feeders and to replace trains and, to a great extent, to perform occasional trips.

The French Railway Companies have subsidiaries who above all carry out services replacing trains. They will disappear once co-ordination is applied.

The Italian State Railways operate a few similar « replacement » services by means of the Istituto Nazionale Trasporti ».

The Netherlands Railways are interested financially in motor concerns carrying on occasional transport and regular lines. The Belgian Railways also operate motorbus lines; but they do not own their own vehicles: they either take them on hire or lease out the operation of the lines.

(b) **Goods traffic.**

As regards goods traffic, the Railways mostly interest themselves in motor services as feeders for their lines. The German State Railways own 2 200 motor lorries, mostly used to serve districts in which there are no railways, but also for long-distance transport on demand and, to a smaller extent, to replace trains. With a view to facilitating the first of these tasks, there have been created, at places far removed from the railway, 6 600 new offices at which goods are accepted.

Most Railways interest themselves in some form or other in goods traffic by road, either with their own vehicles, or by financial participation or, as regards mainly cartage, by means of contractors.

Services that replace railway lines only exist to a modest extent; they are encountered to the greater extent in Holland, where the parcels are carried between railway business centres and their surroundings only by motor lorries belonging to the subsidiary.

As to rates, one may say as a rule that, on replacement services, it is the railway rates, and for feeder services and the fairly rare independent runs to order, special cartage rates that are applied.

As a general rule, participation of railways in goods traffic carried by motor lorries has much less as its object operating savings than the extension of their sphere of action and above all to combat motor competition by means of actual door-to-door transport.

TABLE 1.

Foreign trade (quantities).*(Imports and exports in thousands of metric tons.)**(According to monthly statistical bulletin of the League of Nations.)*

—	1929	1930	1931	1932	1933	1934	1935
Germany	121 548 100	114 060 94	92 772 76	74 400 61	77 220 64	89 628 74	97 512 80
France	99 372 100	97 608 98	88 428 89	71 280 72	73 596 74	74 268 75	73 932 74
Italy	32 268 100	29 760 92	25 428 79	21 360 66	22 500 70	26 520 82	... ...
Austria	14 376 100	11 784 82	10 524 73	7 980 56	7 788 54	8 232 57	8 232 57
Switzerland	9 757 100	9 472 97	9 804 100	9 192 94	8 812 90	8 632 88	8 009 82
Belgium	70 908 100	66 000 93	63 336 89	50 904 72	50 628 71	51 708 73	50 916 72
Netherlands	47 280 100	48 000 102	46 728 99	38 580 82	36 852 78	36 060 76	32 880 70
Denmark	13 229 100	13 407 101	13 549 102	11 943 90	11 782 89	12 216 92	... ...
Sweden	32 800 100	29 255 89	22 206 68	18 370 56	21 104 64	26 426 80	... ...
Norway	11 050 100	10 936 99	8 644 78	9 083 82	9 589 87	10 387 94	... ...
Spain	18 660 100	15 828 85	11 508 62	10 944 59	10 188 54	11 484 62	11 412 61
Hungary	9 468 100	7 176 76	5 232 55	3 420 36	3 624 38	4 032 42	4 416 47
Czechoslovakia	23 131 100	19 360 84	17 105 74	12 281 53	10 781 47	12 032 52	... ...
Poland	26 124 100	22 500 86	21 636 83	15 288 58	15 336 59	17 124 66	16 008 61
Jugoslavia	6 996 100	6 240 89	4 452 64	3 276 47	3 720 53	4 464 64	4 308 62
Japan	27 384 100	24 888 91	23 556 86	23 688 86	27 264 100	31 320 114	35 304 129

TABLE 2.

Foreign trade (value).*(Imports and exports in millions of the currency of the respective countries.)**(According to monthly statistical bulletin of the League of Nations.)*

—	1929	1930	1931	1932	1933	1934	1935
Germany	26 111 100	21 721 83	15 934 61	10 344 40	9 074 35	8 617 33	8 429 32
France	108 360 100	95 352 88	72 636 67	49 512 46	46 860 43	40 956 38	36 408 34
Italy	36 904 100	29 466 80	21 853 59	15 078 41	13 397 36	12 892 35	... ...
Austria	5 451 100	4 551 83	3 452 63	2 148 39	1 923 35	2 010 37	2 100 38
Switzerland	4 829 100	4 326 90	3 600 74	2 564 53	2 447 51	2 279 47	2 105 44
Belgium	67 320 100	57 036 85	46 812 70	30 972 46	28 848 43	27 144 40	32 808 49
Netherlands	4 742 100	4 137 87	3 205 68	2 146 45	1 935 41	1 750 37	1 611 34
Great Britain	1 840 100	1 528 83	1 188 64	1 016 55	994 54	1 076 58	1 128 61
Denmark	3 330 100	3 180 95	2 669 80	2 190 66	2 388 72	2 482 74	2 483 74
Sweden	3 595 100	3 213 89	2 550 71	2 102 58	2 175 60	2 607 72	2 760 77
Norway	1 806 100	1 731 96	1 314 73	1 244 69	1 207 67	1 299 72	1 411 78
Spain	6 045 100	4 747 78	2 137 35	1 714 28	1 505 25	1 472 24	1 462 24
Hungary	2 102 100	1 735 82	1 110 53	663 32	704 33	750 36	855 41
Czechoslovakia	40 459 100	33 185 82	24 882 61	14 830 37	11 686 29	13 662 34	14 147 35
Poland	5 924 100	4 679 79	3 347 56	1 946 33	1 787 30	1 774 30	1 786 30
Jugoslavia	15 516 100	13 740 88	9 601 62	5 915 38	6 260 40	7 452 48	7 730 50
Japan	4 270 100	2 938 69	2 324 54	2 746 64	3 710 87	4 378 102	4 880 114

TABLE 3.

Foreign trade (value).

(Imports and exports in millions of Swiss francs.)

	1929	1930	1931	1932	1933	1934	1935
Germany	32 244 100	26 730 83	19 413 60	12 653 39	11 125 34	10 472 32	10 426 32
France	22 008 100	19 309 88	14 672 67	10 021 46	9 499 43	8 310 38	7 394 34
Italy	10 016 100	7 962 79	5 857 58	3 979 40	3 608 36	3 410 34	... ...
Austria	3 974 100	3 310 83	2 989 52	1 299 33	1 105 28	1 143 29	1 203 30
Switzerland	4 829 100	4 326 90	3 600 74	2 564 53	2 447 51	2 279 47	2 105 44
Belgium	9 717 100	8 211 84	6 718 69	4 440 46	4 156 43	3 903 40	3 726 38
Netherlands	9 877 100	8 585 87	6 643 67	4 455 45	4 028 41	3 642 37	3 356 34
Great Britain	46 361 100	38 324 83	27 735 60	18 318 40	17 024 37	16 745 36	17 009 37
Denmark	4 608 100	4 391 95	3 452 75	2 117 46	1 841 40	1 723 37	1 671 36
Sweden	4 993 100	4 450 89	3 314 65	1 993 40	1 938 39	2 089 42	2 145 43
Norway	2 499 100	2 389 96	1 698 68	1 149 46	1 045 42	1 014 40	1 068 43
Spain	4 601 100	2 847 62	1 046 23	710 15	649 14	618 13	615 13
Hungary	1 902 100	1 565 82	1 002 53	460 24	476 25	471 25	485 25
Czechoslovakia	6 210 100	5 074 82	3 794 61	2 260 36	1 791 29	1 790 29	1 809 29
Poland	3 444 100	2 705 78	1 923 56	1 122 32	1 033 30	1 030 30	1 036 30
Jugoslavia	1 416 100	1 254 88	872 62	489 34	434 31	520 37	540 38
Japan	10 203 100	7 481 73	5 847 57	3 934 38	3 846 38	4 020 39	4 312 42

TABLE 4.

Evolution of passenger traffic.

(In millions of passenger-kilometres.)

—	1929	1930	1931	1932	1933	1934	1935
German State Rys.	47 088 100.0	43 298 92.0	36 922 78.4	30 811 65.4	30 117 64.0	34 831 74.0	39 509 83.9
French main-line Rys.	28 085 100.0	29 124 103.7	28 868 102.8	25 546 91.0	24 583 87.5	23 362 83.2	22 542 80.3
Italian State Rys.	6 662 100.0	7 449 111.8	6 373 95.7	6 051 90.8	6 662 100.0	6 709 100.7	... ...
Austrian Federal Rys.	3 772 100.0	3 507 93.0	3 183 84.4	2 557 67.8	2 310 61.2	2 131 56.5	2 184 57.9
Swiss Federal Rys.	2 937 100.0	3 029 103.1	2 938 100.0	2 776 94.5	2 860 97.4	2 840 96.7	2 707 92.2
Belgian National Rys. Co.	6 365 100.0	6 446 101.3	5 810 91.3	5 157 81.0	5 058 79.5	4 873 76.6	5 109 80.3
British main-line Rys.	31 411 100.0	30 773 98.0	29 041 92.5	28 345 90.2	28 901 92.0	31 757 101.1	32 738 104.2
Netherlands Rys.	3 669 100.0	3 735 101.8	3 516 95.8	3 085 84.1	3 156 86.0	3 054 83.2	2 941 80.2
Danish State Rys.	1 061 100.0	1 108 104.4	1 159 109.2	1 158 109.1	1 058 99.7	1 186 111.8	1 310 123.5
Swedish State Rys.	1 405 100.0	1 534 109.2	1 467 104.4	1 457 103.7	1 496 105.5	1 700 121.0	1 871 133.2
Norwegian State Rys.	493 100.0	511 103.6	524 106.3	510 103.4	522 105.9	510 103.4	525 106.5
Spanish main-line Rys.	3 425 100.0	3 390 99.0	3 119 91.1	3 116 91.0	3 141 91.7	3 029 88.4	2 993 87.4
Hungarian State Rys.	2 608 100.0	2 578 98.8	2 226 85.4	1 784 68.4	1 756 67.3	1 854 71.1	1 884 72.2
Czechoslovak State Rys.	9 020 100.0	8 664 96.0	7 690 85.2	6 958 77.1	6 368 70.6	6 627 73.5	6 349 70.4
Polish State Rys.	7 233 100.0	6 871 95.0	5 604 77.5	4 712 65.1	5 923 81.9	5 296 73.2	5 553 76.8
Jugoslav State Rys.	2 245 100.0	2 230 99.3	2 113 94.1	1 765 78.6	1 697 75.6	1 614 71.9	2 197 97.9
Japanese Govt. Rys.	21 606 100.0	20 392 94.4	19 043 88.1	18 845 87.2	20 470 94.7	22 132 102.4	23 818 110.2

TABLE 5.

Passenger receipts.

(In millions of the currency of the respective countries.)

	1929	1930	1931	1932	1933	1934	1935
German State Rys.	1 375.24 100.0	1 301.45 94.6	1 115.16 81.1	873.34 63.5	821.85 59.8	894.39 65.0	964.85 70.2
French main-line Rys.	3 170.86 100.0	3 261.03 102.8	3 169.91 100.0	2 671.25 84.2	2 610.34 82.3	2 807.20 88.5	2 683.65 84.6
Italian State Rys.	1 536.87 100.0	1 463.33 95.2	1 275.00 83.0	1 135.82 73.9	1 095.19 71.3	1 049.20 68.3	...
Austrian Federal Rys.	216.56 100.0	215.05 99.3	188.30 87.0	165.95 76.6	148.98 68.8	136.48 63.0	135.56 62.6
Swiss Federal Rys.	156.24 100.0	159.12 101.8	150.72 96.5	136.76 87.5	135.21 86.5	133.21 85.2	126.35 80.9
Belgian National Rys. Co.	841.74 100.0	950.15 112.9	843.97 100.3	729.51 86.7	734.03 87.2	696.82 82.8	738.15 87.7
Netherlands Rys.	84.10 100.0	85.33 101.5	79.29 94.3	68.51 81.5	60.50 71.9	56.83 67.6	53.55 63.7
British main-line Rys.	60.02 100.0	57.00 95.0	52.39 87.3	49.18 81.9	49.40 82.3	50.56 84.2	52.06 86.6
Danish State Rys.	49.90 100.0	49.37 98.9	49.86 99.9	47.84 95.9	40.74 81.6	44.79 89.8	47.95 96.1
Swedish State Rys.	63.84 100.0	68.47 107.3	64.13 100.5	59.51 93.2	58.58 91.8	64.52 101.1	69.30 108.6
Norwegian State Rys.	29.09 100.0	29.43 101.2	29.08 100.0	24.56 84.4	25.05 86.1	26.27 90.3	27.11 93.2
Spanish main-line Rys.	189.27 100.0	186.97 98.8	165.51 87.4	161.81 85.5	163.33 86.3	161.53 85.3	163.25 86.2
Hungarian State Rys.	95.50 100.0	93.85 97.2	84.44 87.5	70.98 73.6	66.42 68.8	64.47 66.8	62.58 64.8
Czechoslovak State Rys.	1 106.41 100.0	1 085.32 98.1	1 049.93 94.9	890.36 80.5	810.20 73.2	765.41 69.2	779.32 70.4
Polish State Rys.	390.22 100.0	358.75 91.9	305.48 78.3	244.16 62.6	211.77 54.3	205.41 52.6	206.83 53.0
Jugoslav State Rys.	705.84 100.0	714.69 101.2	661.87 93.8	544.49 77.1	514.10 72.8	500.40 70.9	469.56 66.5
Japanese Govt. Rys.	256.31 100.0	237.52 92.7	216.86 84.6	210.52 82.1	227.42 88.7	244.17 95.3	261.52 102.0

TABLE 6.

Evolution of goods traffic.

(Commercial traffic, excluding service consignments.)

(In millions of tonne-kilometres.)

	1929	1930	1931	1932	1933	1934	1935
German State Rys.	68 936 100.0	54 670 79.3	45 498 66.0	38 905 56.4	41 670 60.4	50 171 72.8	56 954 82.6
French main-line Rys.	44 408 100.0	43 135 97.1	39 352 88.6	33 869 76.3	32 952 74.2	31 483 70.9	28 730 64.7
Italian State Rys.	11 994 100.0	11 734 97.8	10 209 85.1	8 989 74.9	8 323 69.4	7 859 65.5	... ...
Austrian Federal Rys.	4 545 100.0	3 869 85.1	3 199 70.4	2 620 57.6	2 589 57.0	2 743 60.4	2 844 62.6
Swiss Federal Rys.	2 189 100.0	2 042 93.3	1 878 85.8	1 544 70.5	1 551 70.8	1 666 76.1	1 697 77.5
Belgian National Rys. Co.	9 560 100.0	8 125 85.0	6 895 72.1	5 230 54.7	4 566 47.8	4 600 48.1	4 874 51.0
British main-line Rys.	28 301 100.0	26 620 94.1	24 356 86.1	22 262 78.7	22 467 79.4	24 285 85.8	24 580 86.8
Danish State Rys.	593 100.0	644 108.6	620 104.6	578 97.5	479 80.8	510 86.0	532 89.7
Swedish State Rys.	2 959 100.0	2 828 95.6	2 381 80.5	1 583 53.5	1 577 53.3	2 005 67.8	2 433 82.2
Norwegian State Rys.	649 100.0	715 110.2	554 85.4	443 68.2	447 68.9	445 68.6	574 88.4
Spanish main-line Rys.	4 703 100.0	4 637 98.6	4 384 93.2	4 250 90.4	4 104 87.3	3 959 84.2	3 674 78.1
Hungarian State Rys.	2 684 100.0	2 672 99.6	2 249 83.8	1 925 71.7	1 732 64.5	2 062 76.8	1 995 74.3
Czechoslovak State Rys.	11 250 100.0	9 320 82.8	8 281 73.6	6 434 57.2	5 813 51.7	6 370 56.6	7 106 63.2
Polish State Rys.	21 129 100.0	18 359 86.9	18 340 86.8	13 343 63.1	13 946 66.0	14 223 67.3	15 771 74.6
Jugoslav State Rys.	3 564 100.0	3 042 85.4	2 685 75.3	2 203 61.8	2 387 67.0	2 476 69.5	2 643 74.2
Japanese Govt. Rys.	12 581 100.0	11 282 89.7	10 500 83.4	10 541 83.8	11 611 92.3	13 035 103.6	13 976 111.1

TABLE 7.

Quantitative evolution of foreign trade and railway goods traffic between 1929 and 1935.
(1929 = 100.)

	1929	1930	1931	1932	1933	1934	1935
<i>Germany :</i>							
Foreign trade	100	94	76	61	64	74	80
Goods traffic on the German State Rys.	100	82	67	58	63	75	84
<i>France :</i>							
Foreign trade	100	98	89	72	74	75	74
Goods traffic on main-line Railways.	100	98	88	74	72	69	64
<i>Italy :</i>							
Foreign trade	100	92	79	66	70	82	...
Goods traffic on the State Railways.	100	91	76	63	60	63	...
<i>Austria :</i>							
Foreign trade	100	82	73	56	54	57	57
Goods traffic on the Federal Rys.	100	84	72	59	56	54	63
<i>Switzerland :</i>							
Foreign trade and transit	100	96	92	82	79	81	79
Goods traffic on Federal Railways	100	96	92	79	77	77	73
<i>Belgium :</i>							
Foreign trade	100	93	89	72	71	73	72
Goods traffic on the Belgian National Rys. Co.	100	90	79	64	56	57	60
<i>Denmark :</i>							
Foreign trade	100	101	102	90	89	92	...
Goods traffic on the State Railways.	100	108	100	92	70	75	...
<i>Sweden :</i>							
Foreign trade	100	89	68	56	64	80	...
Goods traffic on the State Railways.	100	93	73	52	52	67	...
<i>Norway :</i>							
Foreign trade	100	99	78	82	87	94	...
Goods traffic on the State Railways.	100	118	83	61	55	55	...
<i>Spain :</i>							
Foreign trade	100	85	62	59	54	62	61
Goods traffic on the main-line Rys.	100	98	90	87	83	80	76
<i>Hungary :</i>							
Foreign trade	100	76	55	36	38	42	47
Goods traffic on the State Railways.	100	95	81	58	46	54	53
<i>Czechoslovakia :</i>							
Foreign trade	100	84	74	53	47	52	...
Goods traffic on the State Railways.	100	88	76	57	51	56	...
<i>Poland :</i>							
Foreign trade	100	86	83	58	59	66	61
Goods traffic on the State Railways.	100	81	74	55	55	64	65
<i>Jugoslavia :</i>							
Foreign trade	100	89	64	47	53	64	62
Goods traffic on the State Railways.	100	86	78	64	63	66	71
<i>Japan :</i>							
Foreign trade	100	91	86	86	100	114	129
Goods traffic on the Government Rys.	100	87	77	78	81	89	94

TABLE 8.

Goods receipts.

(Commercial traffic, excluding service consignments.)

(In millions of the currency of the respective countries.)

	1929	1930	1931	1932	1933	1934	1935
German State Rys.	3 358.38 100.0	2 737.42 81.5	2 229.02 66.4	1 667.26 49.6	1 749.18 52.1	2 068.23 61.6	2 245.83 66.9
French main-line Rys.	11 906.21 100.0	11 753.98 98.7	10 530.95 88.4	9 110.32 76.5	8 515.24 71.5	7 800.66 65.5	6 926.32 58.2
Italian State Rys.	2 962.69 100.0	2 653.73 89.6	2 159.55 72.9	1 833.41 61.9	1 611.38 54.4	1 478.12 49.9	...
Austrian Federal Rys.	431.74 100.0	383.38 88.8	331.66 76.8	273.64 63.4	272.10 63.0	278.84 64.6	281.53 65.2
Swiss Federal Rys.	232.09 100.0	218.61 94.2	210.08 90.5	183.47 79.1	179.12 77.2	178.56 76.9	167.73 72.3
Belgian National Rys. Co.	2 613.80 100.0	2 495.83 95.5	2 169.91 83.0	1 663.16 63.6	1 536.98 58.8	1 464.10 56.0	1 420.96 54.4
Netherlands Rys.	91.30 100.0	84.74 92.8	79.95 87.6	66.67 73.0	57.97 63.5	51.79 56.7	44.21 48.4
British main-line Rys.	103.52 100.0	96.51 93.2	87.80 84.8	78.90 76.2	78.53 75.8	83.08 80.2	83.81 81.0
Danish State Rys.	50.79 100.0	53.27 104.9	51.13 100.7	45.76 90.1	36.78 72.4	38.92 76.6	38.93 76.6
Swedish State Rys.	130.89 100.0	119.34 91.2	101.85 77.8	81.57 62.3	82.22 62.8	98.02 74.9	109.18 83.4
Norwegian State Rys.	40.68 100.0	39.39 96.8	34.08 83.8	32.00 78.7	31.35 77.1	31.87 78.3	33.64 82.7
Spanish main-line Rys.	557.36 100.0	558.14 100.1	525.35 94.2	522.23 93.7	499.30 89.6	514.02 92.2	479.16 86.0
Hungarian State Rys.	193.80 100.0	184.66 95.3	152.71 78.8	133.51 68.9	115.51 59.6	130.90 67.5	122.19 63.0
Czechoslovak State Rys.	3 833.52 100.0	3 241.00 84.5	2 939.77 76.7	2 309.67 60.2	2 023.10 52.8	2 125.74 55.4	2 245.31 58.6
Polish State Rys.	1 048.73 100.0	947.85 90.4	834.43 79.6	636.35 60.7	546.53 52.1	570.23 54.4	564.74 53.8
Jugoslav State Rys.	1 827.37 100.0	1 824.45 99.8	1 532.14 83.8	1 223.27 66.9	1 261.46 69.0	1 327.10 72.6	1 384.23 75.7
Japanese Govt. Rys.	237.43 100.0	208.60 87.8	185.67 78.2	...	205.32 86.5	228.72 96.3	244.20 102.8

TABLE 9.

Evolution of operating receipts.

(In millions of the currency of the respective countries.)

—	1929	1930	1931	1932	1933	1934	1935
German State Rys.	5 353.83 100.0	4 570.32 85.4	3 848.67 71.9	2 934.32 54.8	2 920.59 54.6	3 326.33 62.1	3 586.11 67.0
French main-line Rys.	15 907.71 100.0	15 823.43 99.5	14 391.97 90.5	12 268.82 77.1	11 587.68 72.8	11 070.12 69.6	10 035.27 63.1
Italian State Rys.	4 980.70 100.0	4 600.07 92.4	3 853.47 77.4	3 345.88 67.2	3 055.85 61.4	2 884.64 57.9	... ...
Austrian Federal Rys.	704.72 100.0	665.25 94.4	550.78 78.2	474.69 67.4	447.61 63.5	435.79 61.8	437.52 62.1
Swiss Federal Rys.	413.82 100.0	402.89 97.4	386.93 93.5	342.95 82.9	336.62 81.3	333.59 80.6	314.78 76.1
Belgian National Rys. Co.	3 546.69 100.0	3 528.54 99.5	3 090.73 87.1	2 451.98 69.1	2 329.92 65.7	2 215.17 62.4	2 213.58 62.4
Netherlands Rys.	180.78 100.0	175.51 97.1	164.30 90.9	139.54 77.2	122.44 67.7	112.38 62.2	101.12 55.9
British main-line Rys.	182.78 100.0	172.62 94.4	158.50 86.7	145.34 79.5	145.29 79.5	151.14 82.7	153.19 83.8
Danish State Rys.	112.62 100.0	115.17 102.3	114.09 101.3	107.08 95.1	91.91 81.6	100.42 89.2	106.26 94.4
Swedish State Rys.	210.76 100.0	201.58 95.6	181.23 86.0	166.15 78.8	166.14 78.8	183.80 87.2	196.55 93.2
Norwegian State Rys.	77.89 100.0	76.67 98.4	71.57 91.9	64.49 82.8	64.29 82.5	66.32 85.1	68.36 87.8
Spanish main-line Rys.	780.79 100.0	778.22 99.7	722.87 92.6	713.38 91.4	690.11 88.4	701.72 89.9	671.70 86.0
Hungarian State Rys.	310.60 100.0	291.89 94.0	251.54 81.0	218.88 70.5	200.55 64.6	214.78 69.2	203.41 65.5
Czechoslovak State Rys.	5 337.19 100.0	5 041.95 94.5	4 708.97 88.2	3 745.91 70.2	3 377.87 63.3	3 399.45 63.7	3 571.90 66.9
Polish State Rys.	1 596.91 100.0	1 458.87 91.4	1 294.00 81.0	1 009.13 63.2	888.64 55.6	894.55 56.0	892.19 55.9
Jugoslav State Rys.	2 647.72 100.0	2 655.29 100.3	2 382.01 90.0	1 975.81 74.6	1 907.46 72.0	1 979.88 74.8	2 033.90 76.8
Japanese Govt. Rys.	511.20 100.0	462.13 90.4	418.54 81.9	414.10 81.0	450.73 88.2	491.40 96.1	526.74 103.0

TABLE 10.

Evolution of operating expenses.

(In millions of the currency of the respective countries.)

—	1929	1930	1931	1932	1933	1934	1935
German State Rys.	4 493.50 100.0	4 090.35 91.0	3 622.47 80.6	3 001.08 66.8	3 056.59 68.0	3 302.28 73.5	3 433.89 76.4
French main-line Rys.	12 510.60 100.0	13 988.59 111.8	13 698.90 109.5	12 647.81 101.1	12 053.61 96.3	10 991.99 87.9	10 693.12 85.5
Italian State Rys.	4 379.83 100.0	4 124.73 94.2	3 573.49 81.6	3 218.47 73.5	3 190.14 72.8	3 103.62 70.9	... ...
Austrian Federal Rys.	669.49 100.0	656.17 98.0	589.09 88.0	508.80 76.0	475.30 71.0	456.96 68.2	458.34 68.5
Swiss Federal Rys.	280.38 100.0	291.42 103.9	283.28 101.0	273.30 97.5	259.92 92.7	247.57 88.3	240.34 85.7
Belgian National Rys. Co.	3 066.82 100.0	3 208.36 104.6	3 023.94 98.6	2 620.48 85.4	2 343.26 76.4	2 263.15 73.8	2 134.87 69.6
Netherlands Rys.	130.17 100.0	128.82 99.0	127.00 97.6	117.23 90.1	109.46 84.1	104.14 80.0	95.36 73.2
British main-line Rys.	143.93 100.0	139.48 96.9	128.54 89.3	121.28 84.3	119.36 82.9	122.92 85.4	123.53 85.8
Danish State Rys.	109.94 100.0	115.55 105.1	117.29 106.7	112.52 102.3	105.12 95.6	105.47 95.9	109.30 99.4
Swedish State Rys.	161.50 100.0	157.37 97.4	156.64 97.0	153.29 94.9	150.17 93.0	155.20 96.1	161.48 100.0
Norwegian State Rys.	76.83 100.0	78.43 102.1	78.41 102.0	75.77 98.6	71.68 93.3	68.45 89.1	70.29 91.5
Spanish main-line Rys.	561.93 100.0	570.55 101.5	555.67 98.9	545.20 97.0	557.51 99.2	570.17 101.5	561.66 99.9
Hungarian State Rys.	305.11 100.0	287.08 94.1	277.93 91.1	253.90 83.2	255.60 83.8	265.56 87.0	262.93 86.2
Czechoslovak State Rys.	4 989.21 100.0	5 072.30 101.7	4 665.14 93.5	4 445.14 89.1	4 038.28 80.9	3 877.03 77.7	3 938.06 78.9
Polish State Rys.	1 413.89 100.0	1 331.52 94.2	1 187.04 84.0	936.01 66.2	820.71 58.0	774.98 54.8	753.66 53.3
Yugoslav State Rys.	2 623.20 100.0	2 719.59 103.7	2 532.68 96.5	2 005.32 76.4	1 922.24 73.3	1 979.52 75.5	1 922.19 73.3
Japanese Govt. Rys. . . . .	... ...	... ...	261.13 ...	267.50 ...	275.81 ...	306.38 ...	... ...

TABLE 11.

Operation surpluses.

(In millions of the currency of the respective countries.)

	1929	1930	1931	1932	1933	1934	1935
German State Rys.	860.33 100.0	479.97 55.8	226.20 26.3	— 66.76 ...	— 136.00 ...	24.05 2.8	152.17
French main-line Rys.	3 397.11 100.0	1 834.84 54.0	693.07 20.4	— 378.99 ...	— 465.93 ...	78.13 2.3	— 657.17
Italian State Rys.	600.87 100.0	475.34 79.1	279.98 46.6	127.41 21.2	— 134.29 ...	— 218.98 ...	...
Austrian Federal Rys.	35.23 100.0	9.08 25.8	— 38.31 ...	— 34.11 ...	— 27.69 ...	— 21.17 ...	— 20.17
Swiss Federal Rys.	133.44 100.0	111.47 83.5	103.65 77.7	69.65 52.2	76.70 57.5	86.02 64.5	74.55
Belgian National Rys. Co.	479.87 100.0	320.18 66.7	66.79 13.9	— 168.50 ...	— 13.34 ...	— 47.98 ...	78.16
Netherlands Rys.	50.61 100.0	46.69 92.3	37.30 73.7	22.31 44.1	12.98 25.6	8.24 16.3	5.17
British main-line Rys.	38.85 100.0	33.14 85.3	29.96 77.1	24.06 61.9	25.93 66.7	28.22 72.6	29.70
Danish State Rys.	2.68 100.0	— 0.38 44.21	— 3.20 ...	— 5.44 ...	— 13.21 ...	— 5.05 ...	— 3.17
Swedish State Rys.	49.26 100.0	89.7 ...	24.59 49.9	12.86 26.1	15.97 32.4	28.60 58.0	3.71
Norwegian State Rys.	1.06 100.0	— 1.76 ...	— 6.84 ...	— 11.28 ...	— 7.39 ...	— 2.13 ...	— 1.17
Spanish main-line Rys.	218.86 100.0	207.67 94.9	167.20 76.4	168.18 76.8	132.60 60.6	131.55 60.1	11.55
Hungarian State Rys.	5.49 100.0	4.81 87.6	— 26.39 ...	— 35.02 ...	— 55.05 ...	— 50.78 ...	— 5.17
Czechoslovak State Rys.	347.98 100.0	— 30.35 ...	43.83 12.6	— 699.23 ...	— 660.41 ...	— 477.58 ...	— 36.17
Polish State Rys.	183.02 100.0	127.35 69.6	106.96 58.4	73.12 40.0	67.93 37.1	119.57 65.3	13.77
Jugoslav State Rys.	24.52 100.0	— 64.30 ...	— 150.67 ...	— 29.51 ...	— 14.78 ...	0.36 1.5	11.45
Japanese Govt. Rys.	...	...	157.41	146.60	174.92	185.02	...

TABLE 12.

Operating coefficients.

(Ratio % of operating expenses to receipts.)

—	1929	1930	1931	1932	1933	1934	1935
German State Rys.	83.93	89.50	94.12	102.27	104.66	99.28	95.76
French main-line Rys.	78.64	88.40	95.18	103.09	104.02	99.29	106.56
Italian State Rys.	87.94	89.66	92.73	96.19	104.39	107.59	...
Austrian Federal Rys.	95.00	98.64	106.96	107.19	106.18	104.86	104.76
Swiss Federal Rys.	67.76	72.33	73.21	79.69	77.22	74.22	76.35
Belgian National Rys. Co.	86.46	90.93	97.84	106.87	100.57	102.16	96.44
Netherlands Rys.	72.00	73.40	77.30	84.02	89.40	92.67	94.30
British main-line Rys.	78.74	80.80	81.10	83.45	82.15	81.33	80.64
Danish State Rys.	97.62	100.32	102.80	105.08	114.37	105.3	102.86
Swedish State Rys.	76.62	78.07	86.43	92.26	90.39	84.44	82.16
Norwegian State Rys.	98.64	102.30	109.55	117.50	111.50	103.22	102.82
Spanish main-line Rys.	91.97	73.31	76.87	76.42	80.78	81.25	83.62
Hungarian State Rys.	98.23	98.35	110.49	116.00	127.45	123.64	129.26
Czechoslovak State Rys.	93.48	100.60	99.07	118.67	119.55	114.05	110.25
Polish State Rys.	88.54	91.27	91.73	92.75	92.36	86.63	84.47
Jugoslav State Rys.	99.07	102.42	106.33	101.49	100.77	99.98	94.51
Japanese Govt. Rys.	...	...	62.39	64.60	61.19	62.35	...

TABLE 13.

Evolution of the passenger train-kilometres.

(In millions of train-kilometres.)

—	1929	1930	1931	1932	1933	1934	1935
German State Rys.	417.38 100.0	423.13 101.4	421.33 100.9	416.99 99.9	423.18 101.4	448.43 107.4	486.6 116.6
French main-line Rys.	267.62 100.0	275.09 102.8	279.27 104.4	271.60 101.5	272.34 101.8	271.00 101.3	274.4 103.4
Italian State Rys.	86.70 100.0	91.84 105.9	90.02 103.8	91.95 106.1	100.64 116.1	106.72 123.1	110.0 127.0
Austrian Federal Rys.	33.75 100.0	34.69 102.8	33.76 100.0	31.90 94.5	32.01 94.8	33.32 98.7	33.7 99.0
Swiss Federal Rys.	26.95 100.0	28.06 104.1	28.59 106.1	28.69 106.5	28.93 107.3	29.44 109.2	30.0 111.0
Belgian National Rys. Co.	42.39 100.0	44.81 105.7	44.20 104.3	44.66 105.4	49.86 117.6	54.76 129.2	55.0 131.0
Netherlands Rys.	38.71 100.0	39.52 102.1	40.32 104.2	40.57 104.8	40.30 104.1	41.58 107.4	41.0 107.0
British main-line Rys.	401.62 100.0	403.77 100.5	397.78 99.0	398.41 99.2	407.88 101.6	420.94 104.8	431.0 107.0
Danish State Rys.	17.85 100.0	19.40 108.7	17.85 100.0	18.08 101.3	17.69 99.1	17.75 99.4	19.0 107.0
Swedish State Rys.	20.21 100.0	21.83 108.0	22.52 111.4	23.31 115.3	25.00 123.7	27.64 136.8	29.0 145.0
Norwegian State Rys.	9.22 100.0	10.11 109.6	10.98 119.1	11.54 125.2	11.71 127.0	11.89 129.0	12.0 135.0
Spanish main-line Rys.	35.96 100.0	38.74 107.7	35.56 98.9	33.76 93.9	34.46 95.8	37.48 104.2	35.0 99.0
Hungarian State Rys.	29.02 100.0	31.10 107.2	30.41 104.8	27.87 96.0	30.01 103.4	30.59 105.4	30.0 104.0
Czechoslovak State Rys.	70.75 100.0	73.95 104.5	75.79 107.1	79.21 112.0	83.56 118.1	87.58 123.8	89.0 127.0
Polish State Rys.	66.28 100.0	68.42 103.2	68.39 103.2	61.99 93.5	67.19 101.4	66.45 100.2	66.0 100.0
Jugoslav State Rys.	20.60 100.0	21.75 105.6	22.64 109.9	22.81 110.7	23.51 114.1	24.73 120.0	23.0 116.0
Japanese Govt. Rys.	118.07 100.0	... ...	133.07 112.7	137.94 116.8	144.72 122.6	... ...	... ...

TABLE 14.

Evolution of goods train-kilometres.

(In millions of train-kilometres.)

	1929	1930	1931	1932	1933	1934	1935
German State Rys.	259.78 100.0	237.01 91.2	212.90 82.0	190.57 73.4	194.60 74.9	216.73 83.4	239.76 92.3
French main-line Rys.	177.98 100.0	178.35 100.2	158.29 88.9	140.65 79.0	136.14 76.5	138.27 77.7	132.06 74.2
Italian State Rys.	58.51 100.0	53.81 92.0	42.47 72.6	41.79 71.4	45.28 77.4	47.84 81.8	... ...
Austrian Federal Rys.	21.97 100.0	20.46 93.1	18.88 85.9	15.31 69.7	15.17 69.0	15.39 70.0	15.47 70.4
Swiss Federal Rys.	12.43 100.0	12.56 100.8	11.99 96.2	11.32 90.9	11.08 88.9	11.03 88.5	11.02 88.4
Belgian National Rys. Co.	31.89 100.0	28.81 90.3	25.29 79.3	20.24 63.5	19.42 60.9	19.59 61.4	19.54 61.3
Netherlands Rys.	15.56 100.0	15.45 99.3	14.60 93.8	13.77 88.5	13.55 87.1	13.83 88.9	12.26 78.8
British main-line Rys.	224.64 100.0	217.25 96.7	204.08 90.8	192.44 85.7	191.86 85.4	202.16 90.0	203.48 90.6
Danish State Rys.	3.97 100.0	4.39 110.6	6.58 165.7	6.45 162.5	5.87 147.8	5.66 142.6	5.82 146.6
Swedish State Rys.	11.24 100.0	11.21 99.7	11.09 98.7	10.30 91.6	10.61 94.4	12.15 108.1	13.44 119.6
Norwegian State Rys.	4.67 100.0	4.50 96.4	4.36 93.4	4.00 85.6	4.05 86.7	3.86 82.6	4.10 87.8
Spanish main-line Rys.	39.16 100.0	39.08 99.8	35.83 91.5	35.82 91.5	34.72 88.7	35.20 89.9	34.45 88.0
Hungarian State Rys.	10.04 100.0	10.20 101.6	9.02 89.8	8.10 80.7	7.69 76.6	8.47 84.4	8.41 83.8
Czechoslovak State Rys.	46.54 100.0	43.45 93.4	39.01 83.8	34.16 73.4	31.48 67.6	32.91 70.7	35.19 75.6
Polish State Rys.	61.22 100.0	50.89 83.1	48.14 78.6	32.96 53.8	35.19 57.5	37.87 61.8	38.95 63.6
Yugoslav State Rys.	26.60 100.0	25.52 95.9	24.46 92.0	22.03 82.8	20.45 76.9	21.15 79.5	22.38 84.1
Japanese Govt. Rys.	58.20 100.0	... ...	50.61 87.0	51.68 88.8	55.66 95.6	... ...	... ...

OFFICIAL INFORMATION

ISSUED BY THE

PERMANENT COMMISSION

OF THE

International Railway Congress Association

Meeting of the Permanent Commission, held on the 27th February, 1937.

The Permanent Commission of the International Railway Congress Association met on the 27th February 1937 in the Assembly Room of the Belgian National Railways Head Offices at Brussels.

* * *

This meeting was held with the primary object of dealing with the arrangements in connection with the next Congress, which will be held in Paris from the 31st May to the 12th June 1937, and several members of the French Organising Committee came from Paris to attend the meeting.

Mr. RULOT, *President*, in opening the meeting stated that Mr. GUFFLET, Manager of the French Midi Railway, had retired from his position on the 31st December 1936, and therefore had tendered his resignation as a member of the Permanent Commission, in accordance with article 6 of the Rules and Regulations. However, the other French members of the Permanent Commission had proposed that Mr. GUFFLET should remain a member until the Paris Congress and a letter had been sent to all other members to ask for their approval (article 6 of Rules and Regulations).

All the replies received being in favour of this proposal, the Meeting duly approved the same.

* * *

Several new members were then appointed :

Mr. MASARU IWAMURA, Representative of the Ministry of Communications of Japan, Manager of the Berlin Office;

Mr. ION MACOVEI, Inspector General, General Manager of the Rumanian State Railways;

Mr. KRADOLFER, Manager of the « Office Fédéral des Transports » of Switzerland;

Mr. SAUER, Ministerial Councillor at the Ministry of Communications of the German Reich;

Mr. KIRKNESS, Secretary to the Railway Board, Government of India;

to respectively take the place of Messrs. TOMIYAMA, MEREUTZA, HUNZIKER BESSER, and Sir Hugh HANNAY, who resigned (art. 6 of the Rules and Regulations).

* * *

The *President* then informed the Meeting that an invitation had been received,

from the Ministry of Communications of Japan, to hold the 14th Session of the Association in Tokyo, in 1940.

It was decided that this proposal should be submitted to the next Congress which is expected to deal with the proposed date and seat of the 14th Session.

* * *

The *General Secretary* gave information regarding the work in progress at the Executive Offices in connection with the Paris Session. He stated that most of the reports prepared in view of the discussions which will take place at the Congress had already been received and many of them published in the three editions of the monthly *Bulletin* (English, French and German) since September 1936. Only about 15 reports remained for publication in the March, April and May editions, out of a total number of 37 and the work was being actively pushed forward so that all delegates appointed to attend the Congress should receive copies of all these reports before leaving for Paris.

Mr. DE BOYSSON, president of the Executive Committee of the French Organising Commission of the Paris Congress, then acquainted the Meeting with the arrangements in progress and gave a detailed statement of the programme of receptions, excursions, etc., which was being sent to all delegates, including a revised list of the various hotels in Paris, with their prices, etc.

Mr. de Boysson assured the members that all the necessary steps had been taken to ensure the efficient working of the various services which will be called upon to deal with the delegates during the Congress.

* * *

It was announced, in connection with the appointment of the General Officers of the Session, that the PRESIDENT of the French Republic has been pleased to accept to act as Honorary President, and that the vice-presidency will be offered to the French Minister of Public Works. It was also proposed to appoint M. le Baron de ROTHSCHILD, Chairman of the Committee of the French Main-Line Railways, as acting president of the Session, and that two vice-presidents of the Session should be appointed, viz. Mr. LE BESNERAIS, Directeur de l'Exploitation, Chemins de fer du Nord, and Mr. HENRY-GREARD, Directeur Général of the P.O.-Midi Railways.

A decision was also reached regarding the appointment of presidents and vice-presidents for each of the 5 sections of the Congress among the various countries represented at the Session, also regarding the appointment of principal Sectional Secretaries and assistant General Secretaries.

Finally, the appointment of special Reporters who will be called upon to prepare summarised reports on the various questions and to present these at the sectional meetings for discussion, was proposed by the Executive Committee and duly approved.

* * *

The Meeting next dealt with the arrangements made with the various European railways concerned in connection with travelling facilities for delegates. It was stated that delegates will be supplied before their departure for Paris with membership cards which will enable them to reach Paris with the ladies accompanying them.

These membership cards will also ena-

ble delegates only to travel free on all the French railways during a period of two months and on the Paris underground railway and motorbuses during 15 days.

Separate cards will be handed to ladies on their arrival in Paris and will give them similar travelling facilities.

* * *

It was announced that many member Administrations and Governments had sent to the General Secretariat the names of their delegates to the Paris Congress, and that the attendance at the Session is expected to be very numerous.

Invitations will also be sent to the most important technical publications and some daily papers in France and foreign countries to appoint a representative to the Paris Congress. As in the past, these journalists will be allowed to attend plenary meetings and also receptions and excursions in connection with the Congress.

* * *

In accordance with article 6 of the Rules and Regulations of the Association, one third of the members of the Permanent Commission are subject to re-election at each Session and it was decided to communicate with the 22 members whose mandate expires at the Paris Congress to

invite them to accept a renewal of their membership. The appointments will be made at the first meeting of the Permanent Commission to be held in Paris.

* * *

The Meeting was then acquainted with the alterations which occurred in the membership of the Association since the meeting held on the 14th July 1936.

No resignations were reported, and four railways had applied for membership :

New South Wales Government	
Railways	Km. 9 924
Mexican Railway Company	» 700
Thessalian Railway Cy.	» 233
Paris Metropolitan Railways	» 144

Total . Km. 11 001

* * *

The statement of receipts and expenditure for the year 1936 and the provisional budget for the year 1937 were submitted to the Meeting and duly approved.

It was shown that notwithstanding the increased expenditure involved by the Paris Congress the financial situation was very satisfactory.

P. GHILAIN,
General Secretary.

N. RULOT,
President.

List of Members of the Permanent Commission

OF THE

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

(27th February, 1937).

President :

N. **Rulot** ⁽³⁾, directeur général de la Société Nationale des Chemins de fer belges; 231, rue Royale, Brussels.

Vice-Presidents :

U. **Lamalle** ⁽²⁾, directeur général adjoint, directeur de l'exploitation à la Société Nationale des Chemins de fer belges; 17, rue de Louvain, Brussels;

R. **Le Besnerais** ⁽¹⁾, directeur de l'exploitation de la Compagnie du Chemin de fer du Nord français; 18, rue de Dunkerque, Paris.

Members of the Executive Committee :

Grimpret ⁽²⁾, secrétaire général du Ministère des Travaux publics, chargé de la Direction des chemins de fer; 244, boulevard Saint-Germain, Paris;

The Right Hon. Lord **Rockley** ⁽¹⁾, P. C., G. B. E., director, Southern Railway; 2, Cadogan Square, London, S. W. 1;

D. **Vickers** ⁽³⁾, director, London Midland & Scottish Railway; Chapel House, Charles Street, Berkeley Square, London, W. 1.

Ex-president of session, member ex-officio :

H. E. Ibrahim Fahmy **Kerim** Pasha, Minister of Communications of Egypt; Cairo.

Members :

The Hon. E. C. G. **Cadogan** ⁽²⁾, C. B., M. P., director, Great Western Railway; Board Room, Paddington Station, London W. 2;

J. **Castiau** ⁽²⁾, secrétaire général du Ministère des Transports de Belgique; 17a, rue de la Loi, Brussels;

H. E. Mahmoud **Chaker Pasha** ⁽³⁾, under-secretary of State, General Manager of the Egyptian State Railways; Cairo;

M. W. **Clement** ⁽¹⁾, president, Pennsylvania Railroad; Broad Street Station, Philadelphia;

R. **da Costa Couvreur** ⁽¹⁾, ingénieur-inspecteur, secrétaire général au Ministère des Travaux publics et des Communications du Portugal; Rua Chaby Pinheiro, N^o L. V. G., 2, 1^o, Lisbon;

Dautry ⁽³⁾, directeur général des chemins de fer de l'Etat français; 20, rue de Rome, Paris;

Sir Francis **Dent** ⁽³⁾, C. V. O., director, Southern Railway (Great Britain); Dock House, Beaulieu (Hants), England;

de Ruffi de Pontevès ⁽²⁾, inspecteur général des mines, directeur du contrôle du travail des agents du chemin de fer, Ministère des Travaux publics; Paris;

Dr. Othon **de Senn** ⁽¹⁾, secrétaire d'Etat, président de la Direction des Chemins de fer royaux de l'Etat hongrois; 73, Andrassy ut, Budapest VI;

de Spirlet ⁽³⁾, inspecteur général des lignes Nord belges; Liège;

Dr. Ing. eh. J. **Dorpmüller** ⁽¹⁾, Minister of Communications, General Manager of the German State Railways; 35, Voss-Strasse, Berlin W. 8;

(1) Retires at the 13th session.

(2) Retires at the 14th session.

(3) Retires at the 15th session.

- F. **Fiori** ⁽¹⁾, ingénieur, administrateur des chemins de fer de l'Etat italien; Villa Patrizi, Rome;
- Sir Henry **Fowler** ⁽²⁾, K. B. E., chairman of Committee, Ministry of Transport, Great Britain; Spondon Hall, near Derby;
- P. **Ghilain** ⁽²⁾, ingénieur en chef au service du matériel de la Société Nationale des Chemins de fer belges; 231, rue Royale, Brussels;
- A. **Granholm** ⁽²⁾, directeur général des chemins de fer de l'Etat suédois; Stockholm;
- Sir H. Nigel **Gresley** ⁽²⁾, K. B. E., D. Sc., chief mechanical engineer, London & North Eastern Railway; King's Cross Station, London, N. 1;
- Grimpret** ⁽²⁾ (already named).
- Ch. **Guiflet** ⁽³⁾, directeur général honoraire de la Compagnie des Chemins de fer du Midi; 54, boulevard Haussmann, Paris;
- R. J. **Harvey** ⁽³⁾, consulting engineer to the Government of New-Zealand; 34, Victoria Street, Westminster, London, S. W. 1;
- A. **Henry-Gréard** ⁽³⁾, directeur de la Compagnie du chemin de fer de Paris à Orléans; 8, rue de Londres, Paris;
- Sir Cyril **Hurcomb** ⁽¹⁾, K. B. E., C. B., secretary to the Ministry of Transport (Great-Britain); 6, Whitehall Gardens, London, S. W. 1;
- Masaru **Iwamura** ⁽²⁾, secretary of the Japanese Ministry of Railways, Manager of the Berlin Office; 11, von der Heydt Strasse, Berlin W. 35;
- L. **Jacobs** ⁽¹⁾, directeur général de la Société Nationale belge des Chemins de fer Vicinaux; 14, rue de la Science, Brussels;
- G. **Jadot** ⁽¹⁾, directeur du service des finances de la Société Nationale des Chemins de fer belges; 21, rue de Louvain, Brussels;
- H. **Jeziarski** ⁽¹⁾, conseiller ministériel au Ministère des Communications de Pologne; Warsaw;
- E. **Kejr** ⁽³⁾, ingénieur, conseiller ministériel, chef du département V/5 au Ministère des chemins de fer de Tchécoslovaquie; Prague;
- H. E. Ibrahim Fahmy **Kerim Pasha** (already named);
- L. H. **Kirkness** ⁽³⁾, secretary to the Railway Board (India); Simla;
- Dr. Th. **Kittel** ⁽²⁾, Reichsbahndirektor, Deutsche Reichsbahn; 35, Voss-Strasse, Berlin, W. 8;
- P. **Knutzen** ⁽³⁾, directeur général des Chemins de fer de l'Etat danois; 40, Sølvgade, Copenhagen, K.;
- Kradolfer** ⁽¹⁾, directeur de l'Office fédéral des transports de la Confédération suisse; Berne;
- U. **Lamalle** (already named);
- R. **Le Besnerais** (already named);
- C. **Lemaire** ⁽¹⁾, directeur du service de la voie de la Société Nationale des Chemins de fer belges; 17, rue de Louvain, Brussels;
- L. F. **Loree** ⁽³⁾, president, Delaware & Hudson Railroad; 32, Nassau Street, New York City;
- Ion **Macovei** ⁽²⁾, inspecteur général, directeur général des Chemins de fer de l'Etat roumain; Bucharest;
- A. **Mange** ⁽¹⁾, administrateur de la Compagnie du chemin de fer de Paris à Orléans, président du Comité de gérance de l'Union internationale des chemins de fer; 42, rue de la Bienfaisance, Paris;
- A. **Marguerat** ⁽¹⁾, directeur des Compagnies des chemins de fer de Viège à Zermatt, Furka-Oberalp, Gornergrat et Schöllenen; Lausanne;
- E. **Maristany** ⁽³⁾, marquis d'Argentera, directeur général de la Compagnie des chemins de fer de Madrid à Saragosse et à Alicante; Estación de Atocha, Madrid;

(1) Retires at the 13th session.

(2) Retires at the 14th session.

(3) Retires at the 15th session.

- L. **Moralès** ⁽²⁾, vice-président du Conseil supérieur des chemins de fer d'Espagne, président du Conseil d'administration des chemins de fer de l'Ouest de l'Espagne; Estación de las Delicias, Madrid;
- J. **Moreno Ossorio** ⁽¹⁾, Administrateur à la Commission permanente du Comité exécutif des Chemins de fer du Nord de l'Espagne; Estación del Norte, Madrid;
- E. **Mugniot** ⁽³⁾, directeur général de la Compagnie des Chemins de fer de Paris à Lyon et à la Méditerranée; 88, rue St-Lazare, Paris (9^e);
- B. **Nobili** ⁽³⁾, ingénieur, vice-directeur général des Chemins de fer de l'Etat italien; Rome;
- H. E. Mohamed **Osman Bey** ⁽³⁾, under secretary of State, Egyptian Ministry of Communications; Cairo;
- G. **Ottone** ⁽¹⁾, president of the Federazione Nazionale Fascista degli Esercenti Imprese ferroviarie, Tramviarie e di Navigazione; 115, Piazza Montecitorio, Rome;
- Pellarin** ⁽²⁾, directeur de la Compagnie des Chemins de fer de l'Est français; 21-23, rue d'Alsace, Paris;
- J. J. **Pelley** ⁽³⁾, President, Association of American Railroads, Transportation Building; Washington D. C.;
- C. **Ramallo** ⁽²⁾, ingénieur, director del Instituto de Economia de los Transportes, Facultad Nacional de Ciencias Económicas; Buenos Ayres;
- Dr. W. **Rauscher** ⁽²⁾, conseiller ministériel, directeur commercial des Chemins de fer fédéraux autrichiens; Vienna;
- The Right Hon. Lord **Rockley**, P. C., G. B. E. (already named);
- N. **Rulot** (already named);
- Sauer**, Ministerialrat, Reichsverkehrsministerium; 80, Wilhelmstrasse, Berlin W. 8;
- A. **Schraffl** ⁽²⁾, président de la Direction générale des Chemins de fer fédéraux suisses; Berne;
- G. **Sgoureff** ⁽²⁾, ingénieur, directeur général adjoint des Chemins de fer et des Ports de l'Etat bulgare; Sofia;
- Sir Josiah **Stamp** ⁽²⁾, G. B. E., D. Sc., chairman and president of the Executive, London Midland & Scottish Railway; Euston Station, London N. W. 1;
- Surleau** ⁽²⁾, directeur des Chemins de fer d'Alsace et de Lorraine; 3, boulevard du Président Wilson, Strasbourg;
- T. C. **Swallow** ⁽³⁾, advisory engineer, Office of the High Commissioner for the Union of South Africa; South Africa House, Trafalgar Square, London, W. C. 2;
- R. E. **Thomas** ⁽³⁾, deputy general manager, Egyptian State Railways; Cairo;
- Antonio **Valenciano y Mazerès** ⁽²⁾, inspecteur général des ponts et chaussées, administrateur de la Compagnie des Chemins de fer de Madrid à Saragosse et à Alicante; 5-3^o. General Oraâ, Madrid;
- H. **van Manen** ⁽¹⁾, directeur des Chemins de fer néerlandais; Utrecht;
- Th. M. B. **van Marle** ⁽³⁾, inspecteur général des chemins de fer et tramways néerlandais; 25, Koningskade, The Hague;
- L. **Velani** ⁽¹⁾, directeur général des Chemins de fer de l'Etat italien; Villa Patrizi, Rome;
- A. M. M. **Verkoyen** ⁽³⁾, directeur du service du matériel de la Société Nationale des Chemins de fer belges; 17, rue de Louvain, Brussels;
- D. **Vickers** (already named);
- Dr. C. C. **Wang** ⁽²⁾, representative of the Chinese Ministry of Railways; 21, Tothill Street, Westminster, London, S. W. 1;

(1) Retires at the 13th session.

(2) Retires at the 14th session.

(3) Retires at the 15th session.

Sir Ralph Lewis **Wedgwood** ⁽¹⁾, C. B., C. M. G. chief general manager, London & North Eastern Railway; King's Cross Station, London, N. 1;

D. **Willard** ⁽¹⁾, chairman of the Board, Association of American Railroads; president, Baltimore et Ohio Railroad; Baltimore, Md.;

M. **Yoyitch** ⁽²⁾, directeur général adjoint des Chemins de fer de l'Etat yougoslave; Belgrade;

N... ⁽¹⁾ (Brazil);

N... ⁽²⁾ (Germany);

N... ⁽³⁾ (Germany).

N... ⁽³⁾ (Germany).

Honorary member : C. **Colson**, membre de l'Institut, inspecteur général des Ponts et Chaussées, vice-président honoraire du Conseil d'Etat de France, membre du Conseil supérieur des Chemins de fer de France; 2, rue de Laplanche, Paris.

Temporary Members of the Permanent Commission. (Executive Committee of the French Local Organising Commission of the Paris Session, 1937) :

Bacqueyrisse, administrateur, directeur général de l'Exploitation et des Services techniques de la Société des Transports en Commun de la Région Parisienne; 53^{ter}, quai des Grands-Augustins, Paris (6^e);

Barth, ingénieur en chef attaché à la Direction de la Compagnie des Chemins de fer de l'Est français; 21-23, rue d'Alsace, Paris (10^e);

Bugniet, directeur régional de la Compagnie Internationale des Wagons-Lits et des Grands Express Européens; 5, place des Vosges; Paris (4^e);

Cambournac, ingénieur en chef des Travaux et de la Surveillance de la Compagnie du Chemin de fer du Nord français; 18, rue de Dunkerque, Paris (10^e);

de **Boysson**, directeur général adjoint de la Compagnie des Chemins de fer P. O.-Midi; 8, rue de Londres, Paris (9^e);

Delille, directeur de la Société Générale des Chemins de fer Economiques; 4, Cité de Londres, 13, rue de Londres, Paris (9^e);

P. **Martin**, administrateur-délégué, directeur général de la Compagnie du Chemin de fer Métropolitain; 75, boulevard Haussmann, Paris (8^e);

Martinet, ingénieur en chef attaché à la Direction de la Compagnie des Chemins de fer de Paris à Lyon et à la Méditerranée; 83, rue Saint-Lazare, Paris;

Porchez, chef du Service de la Voie, des Bâtiments et de la Construction des Lignes nouvelles des Chemins de fer de l'Etat français; 21, rue d'Amsterdam, Paris;

Vigneau, ingénieur en chef adjoint de l'Exploitation des Chemins de fer d'Alsace et de Lorraine; 3, boulevard du Président Wilson, Strasbourg.

SECRETARY'S OFFICE : 231, rue Royale, Brussels.

General secretary : P. **Ghilain** (already named).

Assistant secretaries : A. W. **Chantrell**, ingénieur principal à la Société Nationale des Chemins de fer belges;

J. **Dubus**, ingénieur à la Société Nationale des Chemins de fer belges;

E. **Minsart**, ingénieur principal à la Société Nationale des Chemins de fer belges.

⁽¹⁾ Retires at the 13th session.

⁽²⁾ Retires at the 14th session.

⁽³⁾ Retires at the 15th session.

RECTIFICATION.

Bulletin, September 1936.

Article : *Main-line electrification throughout the world*, by E. R. KAAH (reproduced by courtesy of *The Railway Gazette*, London).

In the paragraph regarding *Rumania* it is stated that « The electrification of » the Campina-Konstadt section of the State Railways was proposed some time » ago... »

« The scheme has been shelved for the time being owing to a great reduction in traffic... »

We have now received, from the General Management of the Rumanian State Railways, a note containing the remarks we publish hereafter, with apologies for the misstatement :

1. « The traffic on the line in question has never ceased to increase (569×10^6 » gross tonne-kilometres in 1934 — 599×10^6 in 1935 and 618×10^6 in 1936). » Consequently the electrification was not postponed because the traffic declined.

» 2. The line concerned ends at the Campina and *Brasov* Stations. Kronstadt » is not the official name of the latter station, but an old Austrian denomination, » which is no longer used. »
